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A LIMITED LOGICAL ANALYSIS OF PICTURES APPLIED TO A STUDY OF CHILDREN'S RESPONSES TO PICTURES.

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THE DESIGN OF THIS STUDY WAS TO (1) DESCRIBE A WAY OF ANALYZING GRAPHIC OR PICTORIAL MATERIALS, (2) DESIGN SOME STIMULUS MATERIALS WITH THIS METHOD OF ANALYSIS IN MIND, AND (3) TEST SOME PREDICTIONS BASED ON IMPLICATIONS RELATED TO THE ANALYTICAL METHOD IN AN EXPERIMENTAL STUDY. A SET OF GRAPHIC MATERIALS WAS ANALYZED AND DESCRIBED WITHIN A STRUCTURE OF INFORMATION DEVELOPED BY WITTGENSTEIN (1921)--THE "PICTURE THEORY OF LANGUAGE." (FOR WITTGENSTEIN THE PRIMARY FUNCTION OF A PICTURE IS TO REPRESENT AND TO COMMUNICATE ITS REPRESENTATION. IF THE INTENDED REPRESENTATION AND A VIEWER'S INTERPRETATION OF A PICTURE AGREE, THEN THE PICTURE COMMUNICATES.) CONSIDERING THE WITTGENSTEIN CONCEPT, THE INVESTIGATOR DEVELOPED STIMULUS MATERIAL SETS, EACH CONSISTING OF A SAMPLE PICTURE TOGETHER WITH FOUR COMPARATIVE PICTURES. A TOTAL OF 240 SUBJECTS FROM 3 DIFFERENT GRADES PERFORMED "MATCHING-TO-SAMPLE" TASKS USING THESE STIMULUS SETS. TWO RESPONSE VARIABLES WERE STUDIED, SEPARATE SUBJECT GROUPS BEING SELECTED FOR EACH OF THE TWO - A RESPONSE TO SIMILARITY AND A RELATION RESPONSE. OTHER VARIABLES STUDIED WERE DIMENSIONALITY, SCHOOL GRADES, AND BLOCKS OF TRIALS. SEVERAL DEMONSTRATED INTERACTIONS AMONG THESE VARIABLES WERE EXAMINED, AND SOME THEORETICAL PREDICTIONS CONFIRMED. THE RESULTS PROVIDED DATA ON HOW TO USE GRAPHIC MATERIALS FOR EFFECTIVE TEACHING. (JH)

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CHAPTER I

INTRODUCTION

Audiovisualists seem to be dedicated to the principle that learning is facilitated through the extensive use of graphic materials. (The term "graphic materials" will be used as a catch-all for the various graphic and pictorial media such as maps, filmstrips, slides, bulletin boards, displays, pictures, charts, graphs, etc.) The emphasis on the use of motion pictures and television in education must also be attributed largely to the fact that these media include graphic materials. It would seem, therefore, that a major concern of the audiovisual enterprise would be the discovery of the conditions under which graphic materials do, indeed, facilitate learning.

The type of study that has been favored by audiovisual researchers is a comparison of two rather grossly different methods of presenting information, one or both of which may involve the use of graphic materials. In common language, it is said that the independent variable is the medium employed. For example, the effects of the use of a motion picture may be compared with the effects of a teacher's performance in the classroom. Assuming that the students who saw the motion picture presentation scored significantly higher than those who interacted with the live teacher, what can be concluded? Only that this group of students performed better on this particular criterion measure following exposure to this particular motion picture than did another group of subjects after exposure to the performance of a particular teacher.

The independent variable in this example, and in many audiovisual studies, is of such a nature that it subsumes a host of variables. A change in any of them has the possibility of changing the results, and yet these variables are not specified or controlled so that they can be systematically manipulated. Any generalization made from these kinds of comparisons is likely to prove invalid. It might be assumed that media differences are so powerful that these uncontrolled variables are trivial. If that were true, then every comparison of two given media should always be significantly different and in the same direction. Clearly, this has not been the case.

If an investigator wants information to help decide how to teach a particular lesson most efficiently, an experiment comparing two or more methods is appropriate. Such an experiment can provide data by which the several methods compared can be evaluated. However, the results of such an experiment should not be generalized to other examples of the type of material or media tested in the experiment. From the point of view of building up a body of experimental data useful for developing generalizations, these kinds of experiments contribute very little.

In this writer's opinion, the audiovisual field should move from an emphasis on comparing media to an emphasis both on discovering how information may be communicated effectively through the use of graphic materials as well as on the relations between graphic and verbal communication. For example, there is a need to find how these two modes of communication may be integrated to facilitate communication. Further, there is a need to take into consideration individual differences as well as differences with respect to the information to be communicated.

Of course there have been some efforts of this kind in the audiovisual field but they have been few in number and, as will be pointed out later, many have serious shortcomings of one kind or another. It appears that satisfactory relationales and suitable experimental paradigms that will advance the understanding of these problems are still to be discovered. These statements are not intended to imply that learning from graphic materials involves learning processes that are different from those used in learning from other kinds of stimulus materials. The main problem seems to be that graphic materials are so complex (in terms of the amount of information presented) and yet the "parts" of a graphic presentation are tied together into a kind of wholeness which seems to defy analysis.

This study grew out of a concern that one of the factors impeding the development of a science of learning from graphic materials was the lack of a suitable system for describing and analyzing graphic materials. If graphic materials are viewed as means of presenting information, there ought to be some structure of information within which graphic materials can be analyzed and described. One such structure of information is a system of concepts developed by Wittgenstein (1921) for his so-called "picture theory of language." In the next chapter of this study Wittgenstein's analysis of fields of information is discussed and an application of this analysis to graphic materials is made.

A system for analyzing graphic materials, where these are considered to be stimulus materials, has limited usefulness unless it is helpful in demonstrating some relationships between stimuli and responses to these stimuli. A logical system for analyzing graphic materials, if it is to further our understanding of the communication of information, ought to provide the means for making predictions about perceptual or conceptual responses to such materials. In the concept learning field, a language involving dimensions and values of dimensions of the stimulus has been developed for describing and analyzing stimulus materials. Relationships have been found between measures of the analyzed stimulus and difficulty of concept attainment. The similarity of this dimensional analysis and the logical analysis of Wittgenstein will be pointed out in the review of the concept learning literature.

The typical experimental study is the result of an investigator's having an interest in a particular experimental tradition, and through his familiarity with the work that has been published in this area, becoming aware of a problem that suggests the design of a study. Typically, the report of such a study would include a discussion of relevant experimental literature and describe how the new study is related to previous work and how the experimenter expects it to contribute to this particular tradition. The present study does not fit this mold. Rather, the main purpose of this study is to describe a different way of analyzing graphic materials, to design some stimulus materials with this analysis in mind, and to test some predictions based on implications related to the analysis in an experimental study using these materials. The final two chapters will describe, respectively, the study that was done and the conclusions that bear on the analysis.

CHAPTER II

AN ANALYSIS OF PICTURES

One of the purposes of this study is to present a brief description of Wittgenstein's (1921) analysis of fields of information. For this purpose, Stenius's (1960) interpretation of Wittgenstein will be used as a main source. A possible difficulty in reading this paper may be a misunderstanding of the concept of picture as it is used by Wittgenstein. In popular language usage the word "picture signifies a broad range of objects including line drawings, photographs, paintings, etc. To get a better understanding of how Wittgenstein uses the word, the translation from the German of several of his statements that are intended to tell what he considers a picture to be are quoted below. (Wittgenstein, 1961, pp. 15, 19, 37, and 39)

> 2.12 A picture is a model of reality.
>
> 3 A logical picture of facts is a thought.
>
> 4.01 A proposition is a picture of reality.
>
> 4.011 At first sight a proposition--one set on the printed page, for example--does not seem to be a picture of the reality with which it is concerned. But no more does musical notation at first sight seem to be a picture of music, nor our phonetic notation (the alphabet) to be a picture of our speech.
>
> And yet these sign-languages prove to be pictures, even in the ordinary sense, of what they represent.
>
> 4.012 It is obvious that a proposition of the form 'aRb' strikes us as a picture. In this case the sign is obviously a likeness of what is signified.
>
> 4.014 A gramophone record, the musical idea, the written notes, and the sound-waves, all stand to one another in the same internal relation of depicting that holds between language and the world.

> They are all constructed according to a common logical plan.[1]

On the basis of these statements, it will be argued that Wittgenstein has a concept of pictures that is quite different from that in common use. It will be shown that it is questionable whether what is popularly designated as a picture can be included within his definition of a picture. Throughout the remainder of this paper, whenever it is necessary to be clear about which concept of picture is being used, the term "(wc) picture" will signify the Wittgenstein concept of picture and the term "(pc) picture" the popular concept of picture.

An excellent general statement of Wittgenstein's concept of a picture is given by Griffin (1964, p. 87) and may be valuable as a guide through the more detailed account of the concept.

> Suppose we have a fact *p*. There will be an element in its propositional sign '*p*' for each element in *p* and the arrangement of elements in '*p*' will say that the elements in *p* are arranged as they are. Now, consider a person, *A*, thinking the fact *p*. Since a thought, too, is a picture, it must be that *A*'s thought consists of elements (as many as '*p*' had) and that these elements have an arrangement (as those in '*p*' did) which will say that the elements in *p* are arranged as they are....Both '*A* has the thought *p*' and '"*p*" says *p*' assert, in effect, that there is a fact which has *n* elements (*n* being the number of elements in *p*) configured in a certain way, which configuration says that the *n* elements in *p* are arranged as they are. So, they both assert the existence of a relation between two facts: a picturing and a pictured fact; this is why they are of the same form.

In order to explain fully the nature of picturing or representation as it is viewed by Wittgenstein, or more precisely as he is interpreted by Stenius (1960), it will be necessary to include some important related concepts. For example, the name "fact" seems quite important in the above quotation from Griffin. A major emphasis in Wittgenstein's thinking seems to be an orientation toward "facts" rather than toward "things." This orientation is seen in his statement, "A picture is a fact." (Wittgenstein, 1961, p. 15) According to the popular use of the word "picture" this statement seems to be in error. A picture is an object and what is meant by saying that it is a fact is not clear.

---

[1] This final statement makes no mention of pictures but "the internal relation of depicting" is that which is characteristic of a picture.

A System of Categories of Concepts

For Wittgenstein the primary function of a picture is to represent. In his thinking a picture considered as an object does not represent, but a picture considered as a "fact" does represent. (It may be difficult for the reader to appreciate this difference until the concept of a picture is more fully explained.) The distinction between "fact" and "thing" is based on a system of categories of concepts. The purpose of such a system is to group concepts which have the same "logical nature" in one category and to separate into different categories concepts of different "logical nature." The writer is not competent to discuss "logical nature" and it is not considered to be essential to this study. The categories used in the analysis will be specified and some differences among them of a "logical nature" will be discussed.

Probably the most familiar category is the category of concepts of things. Examples of names of thing concepts are the names, "box", "house", "Neanderthal man", and "Johnny Chase's new, purple Sting-ray bicycle." A concept in this category is the name of a set of objects which share some common attribute(s). Any object which has the combination of attributes defined as criterial for membership is a member of the set and is thus an exemplar of the concept.

One characteristic of concepts of the category of things (a characteristic related to the "logical nature" of the category) is the hierarchical relationship among concepts. If concepts a and b are related in a line of increasing generality such that concept b is more general than concept a, then an object which is an exemplar of concept a is also an exemplar of concept b or any other more general concept. If "my next-door-neighbor" is the object to be categorized, he can be thought of as being an exemplar of the concept "citizen of Indiana", "contemporary man", "human being", "mammal", or "thing." This example demonstrates that as concepts become progressively more general the concept named "thing" or "object" or "substance" is reached and it is considered to be the most general concept, than which nothing more general can be found.

It should be quite obvious that all concepts are not included in the hierarchies of thingness. A second very important category of concepts is the category of relational concepts or predicates. Things do not exist independently of relations; they are connected by relational concepts. "Love", "under", and "among" are examples of names of concepts that serve to relate things. A difference in "logical nature" between these two categories is evident in the difference in the inter-concept relations within the two categories. Relational concepts are ordered according to the number of things they relate. Dyadic relations such as "north of", "under", and "father of" connect two things. Triadic relations ("between") connect three things. "Among" is an example of a polyadic relation which connects two or more things but an unspecified number of things. By extension there should be monadic relations as well, and there are, although they are often called qualities. The scholastic logicians considered qualities to be concepts of a unique logical nature and therefore categorized them separately. Modern logicians find it convenient to say that monadic predicates differ from polyadic predicates only in the number of things they relate and group them as relational concepts. "Red", "tall", "stupid", and "new" are names for some monadic relations.

In the discussion of concepts of things it was stated that one way to define a concept was to specify the combination of attributes which an object must have to be considered a member of a concept. The difference between concepts, then, is the difference in the attributes considered criterial to the definition of the concept. Attributes are relational concepts. Therefore, relational concepts play an important role in relating different concepts of thingness although the relationship is dependent on many factors and cannot be readily generalized.

Concepts of things and concepts of relations have been discussed separately but it has been hinted that such a discussion imposes an unnatural bifurcation of combinations that belong together. If "love" is mentioned, an expectation is set up for two things--viz., who is loving and whom or what is being loved. The combination of things and relations also exerts subtle changes in the concepts as can be seen in the changes of redness in the combinations of red face and red barn and red rose. Things and relations belong together; they complement each other.

Combinations or connections of things and relations are what Wittgenstein calls facts. The category of concepts of facts is the third kind of concept in the analysis. The fact that Wittgenstein felt that the category of facts was of special importance has already been mentioned. Stenius (1960, p. 28) summarizes this position in the statement, "The structure of the world is determined by the way the world as a fact is analyzed into simpler 'facts' and how these are apprehended as 'things' and 'predicates'."[2]

The word "fact" is commonly used as a term to signify that a statement is true. This meaning should not be attached to "fact" as it is used in this analysis. A fact is a concept of a certain kind and nothing is implied about the truth or falsity of the concept. This can be illustrated by the expression, "The moon is larger than the earth," which would be classified as a fact since two things are connected in the relation "larger than." However, we know that this particular "fact" is false.

The Concept of Picture

Wittgenstein classifies a picture as a fact. A picture is considered to be a concept of the form which is included in the category of facts. This position is not to deny that pictures are responded to as things. We hang pictures on the wall. Pictures are sold in print shops. Pictures are framed. The sense of "picture" as used in the above sentences would be classified in the category of things. But when pictures are considered as representing something other than themselves they must be considered as facts. This point is clear if representations of things are contrasted with representations of facts. A picture, as a thing, can only be analyzed into components of things that themselves are classified in the category of things. It is possible to produce an infinite number of pictures that all include representations of the same set of things. These pictures must be considered to be identical in their representational function. This concept of representation would have to be rejected as inadequate because it does not give consideration to the arrangement of things in the picture. A picture considered as a fact is analyzable into things and relations of things which include, among other things, the arrangement of things in the picture. This simple comparison illustrates the importance of considering pictures as concepts of the category of facts.

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[2] For the purpose of this analysis, "picture" can be substituted for "world" in this quotation.

Stenius has attempted to tie together the remarks of Wittgenstein into a systematic account of the concept of picture. His statement (Stenius, 1960, p. 96) of the definition of a picture is as follows:

> An articulate field F is called a picture (true or false) of the articulate field G if there is a key of interpretation (C) according to which the elements of F are considered to stand for the elements of G.
>
> The picture F is said to be true or false according as it is an isomorphic picture of G in respect of (C) or not.

Very briefly, if two "fields" are analyzed and the elements of each fact share certain relationships, then one fact is said to be a picture of the other. Wittgenstein in discussing the analysis of the world seems to feel that a logical analysis is like a physical analysis in that the process can be extended until atomic states of affairs composed of atomic things and predicates are reached. These are the elements of a logical space of the world. Stenius states without explanation that Wittgenstein's statements concerning the concept of picture are independent of this idea of logical atomism. Complexes are to be analyzed but the level of analysis is undetermined. What may be considered the things and relations of one analysis may be considered a complex fact to be further analyzed in a different analysis. The term "field" is introduced as a label for complexes that can be analyzed in more than one way. A field that is considered to be analyzed in a particular way is called an "articulate field." An articulate field consists of an analyzed fact and a system of elements (the things and predicates that are the elements of the analysis).

The most expedient way to develop an understanding of the terms "key of interpretation" and "isomorphic picture" is to see how these are operationaly defined through use in the discussion of an example of a picture. There is concern for a complex fact regarding the five male members of the Jones family such that Alan is the father of Brian and Chris: Chris is the father of David and Eric: and Brian and Eric are intelligent. The above analyzed fact will be called the articulate field G. The system of elements of the articulate field is comprised of the five male members of the family, the dyadic father-son relation and the monadic relation of intelligence.

The diagram in Fig. 1 is suggested as a picture of the articulate field G. The diagram may be understood in such a way that the letters a, b, c, d, and e indicate simple things, the circle indicates that a

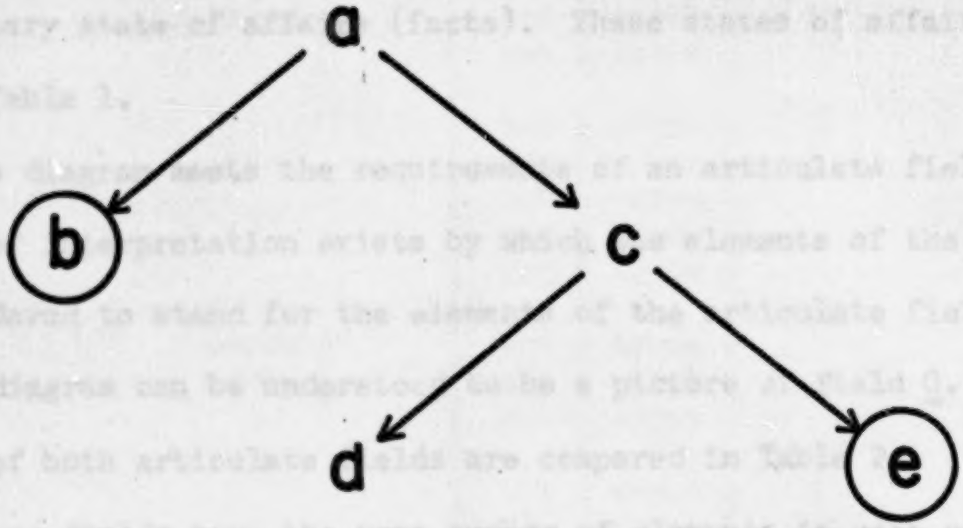

Fig. 1. Field F, a picture of articulate field G

monadic relation is connected to the letter it surrounds, and the arrow indicates that a dyadic relation connects the two letters at its extremities. When the diagram is analyzed in this way, a system of elements exists. This is one of the requirements for an articulate field. It has been stated that an articulate field also consists of an analyzed fact. One way of expressing the analyzed fact is to consider every possible combination of elements that goes to make up an elementary state of affairs (facts). These states of affairs are given in Table 1.

The diagram meets the requirements of an articulate field. If a key of interpretation exists by which the elements of the diagram are considered to stand for the elements of the articulate field *G*, then the diagram can be understood to be a picture of field *G*. The elements of both articulate fields are compared in Table 2.

These fields have the same number of elements in each category.[3] When such a condition exists the two fields are said to have identical categorial structures which is a necessary condition for the establishment of a one-to-one correspondence between elements of like categories in the two fields. The key of correspondence is a one-to-one matching of elements of like category in both fields. In this example, there is only one way to match elements in the two relational categories but there are 120 ways that the five things could be matched. The elements will arbitrarily be matched according to their listing in Table 2, i.e., *a* stands for Alan, *b* stands for Brian, etc. In other

---

[3] In comparing systems of elements each degree of relation is considered to be a different category although no division of the category of things is indicated by Stenius.

Table 1

Existent and Non-existent States of Affairs in Fig. 1

Existent states of affairs	Non- existent states of affairs
a arrow *b*	not *a* arrow *a*
a arrow *c*	not *a* arrow *d*
	not *a* arrow *e*
	not *b* arrow *a*
	not *b* arrow *b*
	not *b* arrow *c*
	not *b* arrow *d*
	not *b* arrow *e*
c arrow *d*	not *c* arrow *a*
c arrow *e*	not *c* arrow *b*
	not *c* arrow *c*
	not *d* arrow *a*
	not *d* arrow *b*
	not *d* arrow *c*
	not *d* arrow *d*
	not *d* arrow *e*
	not *e* arrow *a*
	not *e* arrow *b*
	not *e* arrow *c*
	not *e* arrow *d*
	not *e* arrow *e*
b is circled	*a* is not circled
e is circled	*c* is not circled
	d is not circled

words, the pairing of an element in each column in Table 2, in the order of pairs from top to bottom establishes a one-to-one correspondence or interpretation. The diagram in Fig. 1 fulfills all the requirements for being a picture of the articulate field *G* according to the definition previously given.

Table 2

Comparison of Elements in Fields *F* and *G*

	Elements of field *F*	Elements of field *G*
Things	*a* *b* *c* *d* *e*	Alan Brian Chris David Eric
Monadic relation	circle	intelligence
Dyadic relation	arrow	father-son

The only question that remains is whether it is a true picture or not. If the diagram is an isomorphic picture of field *G*, it is a true picture; otherwise it is a false picture. Stenius (1960, p. 93) defines isomorphism as follows:

> Given two articulate fields *F* and *G*, the categorial structure of which is the same, and given a one-to-one correspondence (*C*) between the elements of each category in *F* and *G*, then *F* and *G* are said to be *isomorphic* in respect of (*C*) if, and only if, the following condition is fulfilled:
>
> *An elementary state of affairs does or does not exist in F according as the corresponding elementary state of affairs does or does not exist in G.*

The elementary states of affairs of the diagram have already been given. The elementary states of affairs for the articulate field G can be deduced from the statement of the complex fact concerning the Jones family and are given in Table 3.

Table 3
Existent and Non-existent States of Affairs in Articulate Field G

Existent state of affairs	Non-existent state of affairs
Alan is the father of Brian Alan is the father of Chris	Alan is not the father of Alan Alan is not the father of David Alan is not the father of Eric
	Brian is not the father of Alan Brian is not the father of Brian Brian is not the father of Chris Brian is not the father of David Brian is not the father of Eric
Chris is the father of David Chris is the father of Eric	Chris is not the father of Alan Chris is not the father of Brian Chris is not the father of Chris
	David is not the father of Alan David is not the father of Brian David is not the father of Chris David is not the father of David David is not the father of Eric
	Eric is not the father of Alan Eric is not the father of Brian Eric is not the father of Chris Eric is not the father of David Eric is not the father of Eric
Brian is intelligent Eric is intelligent	Alan is not intelligent Chris is not intelligent David is not intelligent

A comparison of the two sets of elementary states of affairs shows that the analyses and correspondences established do result in a correspondence of elementary states of affairs. Any thing in the system of field F that is circled has its corresponding thing in the system of field G to be connected with the corresponding monadic relation of intelligence. Any pair of objects in the system of field F that have the arrow relation connecting them have the corresponding pair of things in the system of field G connected by the corresponding relation of "father-son." Field F, as analyzed and interpreted, is isomorphic to field G and is a true picture of the state of affairs in that articulate field.

The above paragraphs are a fairly adequate general description of Wittgenstein's concept of representation. Several details need more discussion. However, it seems expedient at this point to apply the concepts that have been developed to the problems for which concern is held.

Are Photographs Pictures?

A first problem to consider is whether exemplars of (pc) pictures are also exemplars of the concept of (wc) picture as defined above. To be so considered, three conditions must be fulfilled. The prospective picture must be an articulate field: i.e., it must be organized into sets of existent and nonexistent elementary states of affairs (an analyzed fact) composed of connections among a system of elements. Secondly, the articulate field must have an identical categorial structure with the pictured fact. Finally, a key of correspondence must establish a one-to-one matching of elements of each category between the picture and the fact represented by the prospective picture. (The question of isomorphism determines whether the picture is true or false but is not essential to the definition of a picture).

Do (pc) pictures meet the above requirements? Stenius contends that they do not. Stenius seems to imply that there ought to be rules determining the analysis and interpretation of (pc) pictures and that these rules ought to be independent of any consideration of the truth or falsity of the (wc) picture. Stenius does not believe that such rules exist and he (Stenius, 1960, p. 112) argues that,

> Our endeavor to find a 'reasonable' interpretation... affects both the analysis of the picture field and the choice of the key of interpretation. Thus the interpretation is perhaps not wholly independent of at least the believed 'truth' or 'falsehood' of the picture.

These remarks direct attention to the process of analysis. In several places Stenius gives the impression that there are rules by which the analysis is determined. One of the examples he gives is the analysis of a field of perception where he attributes the analysis to the operation of the Gestalt "law of proximity." The fact that Wittgenstein gives no consideration to the problem of how a fact is analyzed might be taken as evidence for the interpretation that the analysis is determined by simple rules.

On the other hand both Wittgenstein and Stenius discuss the fact that fields can be analyzed in more than one way. Wittgenstein (Wittgenstein, 1960, p. 111) presents a drawing of a Necker cube with the following statement:

> To perceive a complex means to perceive that its constituents are related to one another in such and such a way. This no doubt also explains why there are two possible ways of seeing the figure as a cube; and all similar phenomena. For we really see two different facts.

An alternative conclusion might be that there is more than one rule that is applicable to the process of analyzing and interpreting and that it is necessary to have recourse to a further rule to explain which of the first set of rules is applicable in a given situation. A more likely alternative for a logician would be to remove the problem from his concern by classifying it as a psychological problem. Stenius (1960, p. 26) does in fact take this position in his discussion of the analysis of a field of perception.

> The field of perception is thus organized so that those facts emerge which are of theoretical or practical 'interest' to the person perceiving--it is analyzed so that what could be called relevant facts emerge. And what things and predicates are perceived depends on what facts are relevant.

If the analysis of perceptual fields is considered to be a psychological process then, the analysis of (pc) pictures should also be so considered since the process in either case must be very similar. Then the question of whether a (pc) picture is analyzed and interpreted according to a fixed pattern must be a problem for empirical investigation. It cannot be concluded a priori that such a fixed pattern does not operate. The popular notion that pictures are of the nature of an international language provides an extremely rough index to the notion that (pc) pictures are analyzed in fairly fixed patterns (if they are in fact subject to such a process of analysis at all).

Additional comments of Stenius indicate that it apparently is not simply a question of a fixed process of analysis and interpretation that is at the heart of his objections to including (pc) pictures as (wc) pictures. Stenius (1960, pp. 94-95) presents a diagram (Fig. 1) and an analysis of the diagram with the comment,

> This step (the analysis) is by no means trivial. For we could certainly apprehend our diagram as an articulate field in many other ways too. And the only reason why the field should be analysed in exactly this way is that this is the analysis relevant for the interpretation of....(the diagram) as a picture. (The parenthetical expressions were added.)

Stenius then presents the key of correspondence between the elements of the diagram and the elements of the field represented by the diagram. In a footnote he gives as the reason for analyzing the diagram into the particular set of elements given that these are the elements that appear in the key of correspondence. Stenius seems to be saying that the process of analyzing (and interpreting) a field is affected by an understanding of what is necessary in order that a field be considered as a picture. This is reasonable but is contrary to the idea of a fixed analysis determined by rules. It suggests the possibility that analyses can be "tried on" until one is found that fits.

Fig. 2 is a flow diagram of a process that is to be understood as a possible model of the sequences of operations that may satisfy the conditions suggested by Stenius in the preceeding paragraph.

This model is appropriate in the context where an analyzed fact (or a field to be analyzed) is given and a second field is purported to be a picture of the first. The question is to determine whether it is a picture or not. The question can only be answered after the field

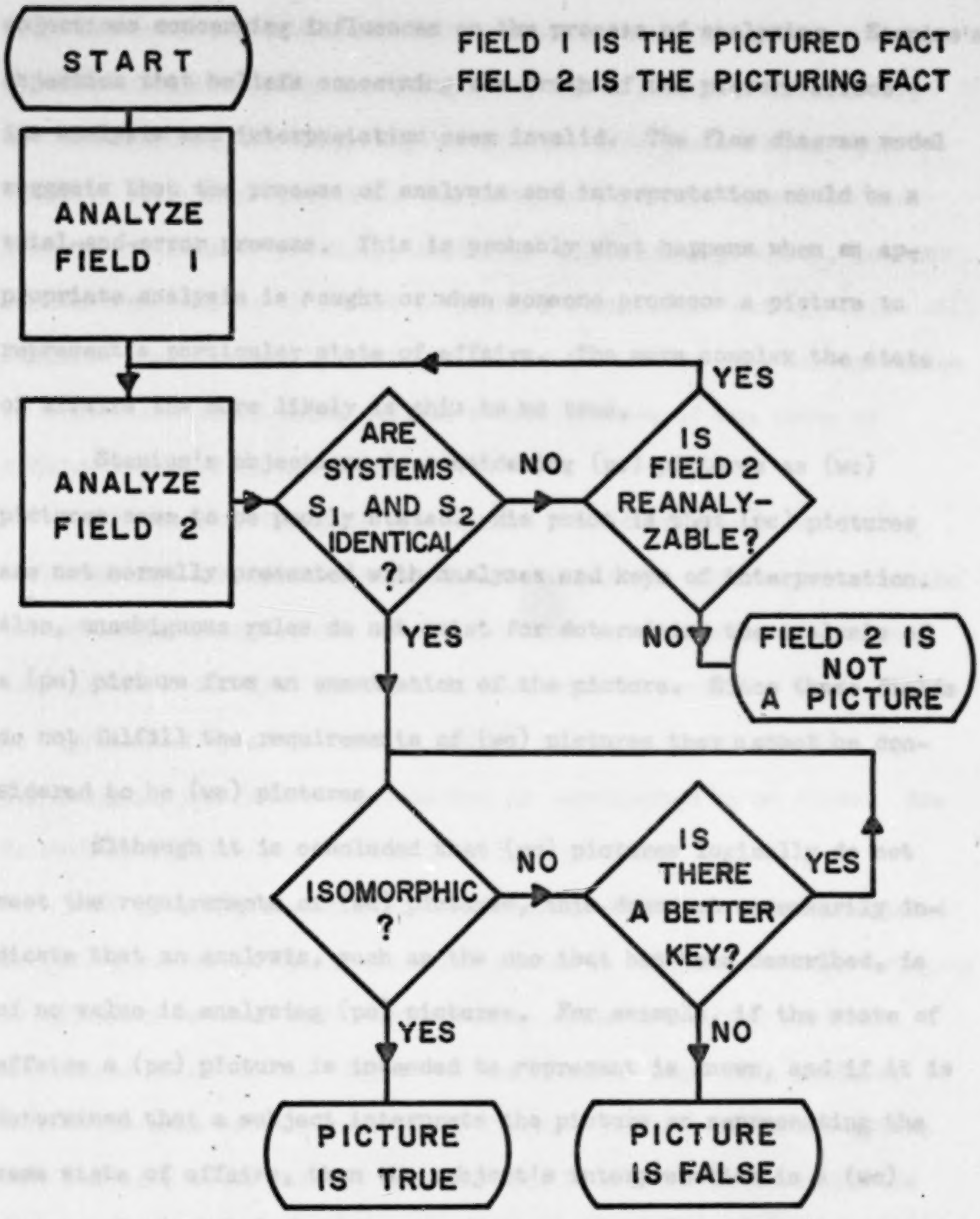
START
FIELD I IS THE PICTURED FACT
FIELD 2 IS THE PICTURING FACT
ANALYZE FIELD I
ANALYZE FIELD 2
ARE SYSTEMS S_1 AND S_2 IDENTICAL ?
NO
YES
IS FIELD 2 REANALYZABLE?
YES
NO
FIELD 2 IS NOT A PICTURE
ISOMORPHIC ?
NO
IS THERE A BETTER KEY?
YES
YES
NO
PICTURE IS TRUE
PICTURE IS FALSE

Fig. 2. A flow diagram model of the process of analyzing and interpreting a field.

has been analyzed and interpreted. There seems to be no basis for objections concerning influences on the process of analyzing. Stenius's objection that beliefs concerning the truth of the picture affect its analysis and interpretation seem invalid. The flow diagram model suggests that the process of analysis and interpretation could be a trial-and-error process. This is probably what happens when an appropriate analysis is sought or when someone produces a picture to represent a particular state of affairs. The more complex the state of affairs the more likely is this to be true.

Stenius's objections to considering (pc) pictures as (wc) pictures seem to be poorly stated. His point is that (pc) pictures are not normally presented with analyses and keys of interpretation. Also, unambiguous rules do not exist for determining the analysis of a (pc) picture from an examination of the picture. Since these fields do not fulfill the requirements of (wc) pictures they cannot be considered to be (wc) pictures.

Although it is concluded that (pc) pictures logically do not meet the requirements of (wc) pictures, this does not necessarily indicate that an analysis, such as the one that has been described, is of no value in analyzing (pc) pictures. For example, if the state of affairs a (pc) picture is intended to represent is known, and if it is determined that a subject interprets the picture as representing the same state of affairs, then the subject's interpretation is a (wc) picture of the original state of affairs. Also if subjects agree in making a common response to a picture, to the degree that this response is determined by the subjects interpretation of the picture, the subjects must agree in their interpretation of the picture.

The logical analysis seems valuable as a language for describing and analyzing pictures. Such a description process may aid the picture disigner in stating the informational intent of the picture and in analyzing and comparing the picture with the statement of intent. From this viewpoint, the designer's purpose cannot be described in terms of producing realistic or abstract pictures, but it can be described as an effort to produce a pictorial message which will maximize the probability that the intended audience will conceptualize an articulare field which will be a (wc) picture of the state of affairs intended by the designer.

The logical analysis may suggest some predictions concerning relationships between the analysis of the picture and responses to the picture. For example, one of the most obvious differences between (wc) pictures and (pc) pictures is that each element of a (wc) picture is represented by an element (a thing) in the picture. In Fig. 1, for example, the father-son relation is represented by an arrow. How is such a relation represented in a (pc) picture?

In general, elements of the category of things are represented in (pc) pictures as "point-at-able" elements. Elements of the category of relations have no such corresponding elements in (pc) pictures. One cannot point at the "under" or the "taller than" in a picture. This difference between conceptual elements in (pc) picture suggests that subjects would find it more difficult to match pictures on the basis of identical relations than on the basis of identical things. Adult subjects may not demonstrate such a difference because of extensive interpreting and responding to visual displays of all kinds, but there is some evidence that children's responses to pictures change with age. It was predicted that there would be less difference in difficulty between older and younger children learning to match pictures on the basis of identical things (figures of people) as compared to learning to match pictures on the basis of identical relations (facing directions). This hypothesis was tested in the study reported in Chapter IV.

CHAPTER III

REVIEW OF LITERATURE

The major purpose of this study has been described as the development of a system for describing and analyzing graphic materials. Audiovisual research has been concerned with instruction with graphic materials. It would seem to be the field in which to find reports of methods for describing and analyzing graphic materials. Very few studies of this type are reported. Many audiovisual experiments present very complex fields of information to subjects. One complex field of information differs from another in so many ways that differences in responses to two such different fields cannot be related to describable changes between the stimuli. Therefore, the response differences noted cannot be generalized to any population of stimuli. A descriptive system is needed both for the purpose of describing populations of stimulus materials and as a means of controlling and standardizing stimuli and changes in the stimuli. A few audiovisual studies that have related graphic stimulus variables with response measures will be reviewed. These studies are included primarily as demonstrations that methods of analyzing graphic stimulus materials that have been used are not satisfactory when the experimenter is concerned with the transmission of information with graphic materials.

The transmission of information, expecially when fields of information are analyzed into a structure of categories of concepts, suggests that experimental studies with graphic stimulus materials may have some relationship to concept learning studies. More specifically, the study reported in Chapter IV is closely related to concept learning studies. In this study, a picture matching to sample task is used where the basis for matching is a recognition of representations of identical concepts, but the category of the concept varies between groups of subjects. Several concept learning studies where the independent variables were stimulus variables are reviewed.

In an exploratory study such as this one, it is difficult to anticipate the effect that stimulus variables may have on performance. Prior experimental evidence indicated that children's verbal responses to pictures change with age. It was decided to utilize this developmental factor to study differences in responses in the study that is reported in Chapter IV. In order to develop some relationships between age and concept learning, several studies of concept learning with children are reported in this chapter.

A few studies from areas other than these three are included in the audiovisual section of the chapter.

Hunt (1962) has suggested the use of a precise language which makes possible the application of set theory to concept learning. This language has some of the same names as those that were introduced in the discussion of Wittgenstein's logical analysis but the referent of the name is different in the two discussions. Also, different names are used in the two discussions to refer to the same thing. These differences and similarities will be pointed out. The similarities are impressive and suggest the possibility that with careful control of graphic stimulus materials it may be possible to discover relationships between these materials and the very simple, abstract materials used in most concept learning experiments.

Audiovisual Research Employing Picture Variables

In the audiovisual field a relatively large number of studies has been performed to evaluate the effect of manipulating simple physical attributes of pictures on the preference ratings of the pictures by subjects, generally children. A review of most of these studies (University of Illinois, 1952) has summarized this research as indicating that large, colored photographs (or realistic illustrations of high quality) are most preferred. These studies will not be presented in detail because it is not known how to relate attractiveness of picture to conception of the information content of pictures. The attractiveness of a picture may increase the probability that a subject will expose himself to the picture.

A theory of textbook illustration was proposed by Smith (1960, pp. 48-49) and was the basis for the design of a psychology textbook and workbook. Three functions of art in textbooks were proposed but the only empirical evidence given to support this theory is the following claim:

> Over 80 per cent of 150 students in a beginning class in psychology in one of the outstanding educational institutions of the country reacted to the illustrated textbook as a well organized book. The same reaction to the other one as a well organized book was considerably less.[1]

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[1] The other book was described as an equivalent scientific

In order for this theory to become attractive, it is necessary that hypotheses be derived from the theory and tested empirically. The evidence given is of very doubtful value.

Williams (1939) chose 13 children's books, in the field of science, from each of three categories of usage (high, middle, and low) as determined from library records. These books were made available to 37 fifth grade and 59 sixth grade students in groups of 15 to 20 for six free reading periods. Williams observed and recorded the behavior of the children during these periods, and, at the end of the sessions, interviewed each child and recorded his verbal responses.

Williams recorded considerable data but did not use statistical methods to analyze the data. Her impressions, based on the observations and interviews, seem valuable. She states that for these children, illustrations were the most important feature in the format of a book. "Meaningful illustrations" were deemed very valuable by which she apparently meant illustrations that were not too complex or obscure for the children to interpret appropriately, and which presented material integrated with the textual material of the book. Although photographs seemed to be favored, the more important criterion was whether the picture "conveyed meaning." A critical comment from the study was that very few children finished reading a book to which they were indifferent.

The reports of both Smith and Williams are difficult to evaluate since objective statistical comparisons were not applied to the data.

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textbook on human behavior consisting of a rigorous logical approach to the subject.

They seem to support the notion that in these cases where self motivation operates in the selection of materials, and where self motivation is necessary to sustain interest in the materials, "attractiveness" may well be an important factor. It may be possible also, that if the intended purpose of the picture is to present information, that the presentation of a picture high in aesthetic value (attractiveness) will interfere with the communication of information. There may be an optimum value of attractiveness from which both upward and downward deviations may have an adverse effect on the communication of information from the picture. This problem has apparently received no attention by researchers.

Another study has examined textbooks in several areas to compare the visual materials used in these different areas. A content analysis of the types of graphic stimuli presented and the graphic responses required in 16 high school textbooks in algebra, biology, and music, currently in use in Boston, Mass., was reported by Hickey (1963). The purpose of the analysis was to establish criteria for the design of a teaching machine that presents graphic stimuli and accepts graphic responses.

Graphic stimuli and responses were defined in this study in such a way as to include everything except conventional verbal textual materials and spoken or written verbal responses. The types of stimuli and responses classified as graphic are more inclusive than those found in most classification systems.

Significant differences in the profiles of types of graphic stimuli and types of graphic responses were found among the texts of three subject matter areas which were compared. Table 4 lists the four most frequently found stimulus response (s-r) pairs for each subject matter area and the percentage of the total number of s-r pairs included in each of these categories.

The data of Table 4 suggests that at least some subject matter areas had idiosyncratic stimulus-response pairs. These accounted for a large part of the differences in profiles reported in the study. It is also interesting to note that the four most frequent s-r pairs accounted for nearly all the s-r combinations for music, three-fourths of the combinations for biology, and only one-third of the combinations for algebra. The highest percentage of total responses attributed to a non-graphic s-r combination (verbal stimulus-verbal response) among these three subjects was in biology (39%).

Hickey concluded the report with an expression of disappointment. He felt that both the presentation of graphic stimuli and the requirement of graphic responses were stereotyped, limited, and supplemental in these textbooks. The study raised several questions of practical concern for which there are no immediate answers. Were the experimenter's preconceptions unrealistic? Is a rich interaction of verbal, graphic and numeric modes of information presentation and student response necessary and desirable for effective learning? Is the present state of the art of textbook production failing to provide effective materials? Did the sample of textbooks studied deviate from the average in the use of graphic materials?

Fleming (1965) has proposed a study similar to that of Hickey's that will be applied to four subject areas at the junior high level.

Table 4

A Comparison of the Percentage of Total Responses of the Four Most Frequent Stimulus-Response Pairs in Three Subject Areas

Subject Areas	Stimulus	Response	Percent
	Numeric question	Perform numeric operation	12.24
	Combined verbal and numeric question	Perform numeric operation	8.65
Algebra	Numeric question with verbal instruction	Perform numeric operation	7.17
	Graph in color	Associate graphic and verbal stimulus	5.06
			33.12
	Verbal question	Answer verbally	39.23
	Photograph in black and white	Associate graphic and verbal stimulus	21.53
Biology	Line drawing in color	Associate graphic and verbal stimulus	12.67
	Line drawing in black and white	Associate graphic and verbal stimulus	4.68
			78.11
	Line drawing in black and white	Vocalize	75.00
	Verbal question	Answer verbally	13.28
Music	Line drawing in black and white	Take interest in a text objective	4.05
	Photograph in black and white	Associate graphic and verbal stimulus	2.70
			95.03

He states that a necessary step toward a systematic study of learning as a function of instructional illustration is a typology of physical types of illustrations. He proposes to use categories quite similar to those used by Hickey.

The purpose of Hickey's study was to develop criteria for the design of a "graphic teaching machine." Most current teaching machines are not designed to use graphic materials. By examining the use of graphic stimuli and the requirement of graphic responses in textbooks, criteria for the design of a graphic teaching machine can be suggested. If attention is given to programs and machines combining graphic, numeric and verbal stimuli and responses, perhaps significant advances will be made in better understanding the roles of these different modes of presentation of information.

The main purpose of Fleming's study seems to be the formalization of a taxonomy of instructional illustrations. This experimenter is skeptical that Fleming's study will make a contribution to a taxonomy of instructional illustrations.

It is this experimenter's opinion that the kinds of responses that are likely to be of interest in studies of practical learning problems from pictorial illustrations do not have reliable or understandable relationships to the kinds of differences in pictorial illustrations that Fleming proposes to use as categories of his taxonomy. It is expected that students interpret textbook illustrations as representing certain states of affairs. The elements of these states of affairs are concepts. If Fleming's taxonomy is [illegible] be relevant to instruction with graphic materials, it must demonstrate some reliable relationships between the categories of the taxonomy and the interpretation of pictures. For example, if color and black and white are values of a significant picture variable, then changes in this variable should result in reliable changes in interpretation. When the response class of interest is interpretation of pictures, simple physical changes of this type between pictures, do not seem to be promising variables for a taxonomy of instructional illustrations.

Fleming does not indicate an interest in any particular class of responses. He refers to the study of learning as a function of instructional illustrations. It is suggested that no taxonomy is likely to be useful to the many different classes of responses that might be considered to be parts of learning processes. As a matter of procedure, it may be expedient to develop a taxonomy which is useful in the study of limited aspects of learning. The taxonomy can be further developed or modified for application to other areas.

Experimenters have investigated some classes of responses that play a part in learning from pictures. These reports have provided evidence useful in organizing a formal taxonomy. These data may contain suggestions concerning the beginnings of a taxonomy. The results of additional studies related to the taxonomy will suggest changes in the taxonomy. This research project is one attempt to follow this pattern in considering a logical analysis of pictures as one possibly useful system for describing instructional illustrations.

Several experimenters have manipulated pictures by systematically removing "details" from a picture to produce variants of the original picture. The terms "concrete" and "abstract" are sometimes applied, respectively, to the original picture and to the final schematized version. One example of such a study was conducted by Ryan and Schwartz (1956). They photographed three objects that were selected in such a way that elements of the objects could be represented in one of four different configurations. The objects were a hand with thumb touching one of four fingers, a group of five knife switches with one switch open, and a cross section of a steam valve with the piston in one of four stages. Three versions of every photograph were derived from the original photographs: a shaded drawing with two shades of gray, a line drawing, and a cartoon line drawing where "we distorted the figure to emphasize the essential spatial relationships involved." (Ryan and Schwartz, 1956, p. 61). The stimuli were presented tachistoscopically in a single ascending series of a randomized order of the 16 illustrations of one object. The subject was told what the object was; and that he was to respond either by reproducing the thumb-finger position, naming the open switch, or identifying the cycle of the steam valve, as the case may be.

The assumption involved in this study was that an important criterion for the effectiveness of an illustration is the speed with which relevant details can be perceived. A difference was found in the speed of perception of the illustrations; fastest to slowest, they were cartoon, photograph, shaded drawing, and line drawing.

As a part of a larger study, Fleming (1960) made color transparencies of four objects. Prints of the originals were further treated by air-brushing out attributes of form and surface features that were particular to individual objects rather than to classes of objects. The third level of illustration was an outline drawing of the basic form of the object. All 12 pictures were individually projected to each of 30 seventh grade students. The subjects were asked to name the pictures. Judges ranked the free naming responses from most inclusive to least inclusive. Later, all three illustrations of each object were projected simultaneously. The subjects matched numbers identifying each picture with the one most appropriate of a set of six prepared names. The list of names included both different nouns and noun phrases consisting of the same noun with one or more modifiers. In both of these measures significant differences were found in a direction indicating that the least inclusive names were paired with the color transparency and the most inclusive names were associated with the line drawing transparency.

These two studies were different in several ways. However, the progressive schematization of the pictures in both experiments (where illustrational levels are comparable) seem to be very similar operationally.[2] The results of the two studies cannot be compared because the types of responses observed were different in the two experiments. Examination of the Ryan and Schwartz stimulus materials suggests that if naming responses were collected for the various levels of these stimuli, as was done in the Fleming study, the kind of naming response differences Fleming found would not be observed. If this is true, and if other results of these studies are considered, it suggests that if the changes made to illustrations are simple changes in the physical dimensions of the picture without regard to the informational structure of a higher order combination of physical characteristics, responses that are related to this higher order informational structure will be affected in an unpredictable manner.

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[2] Fleming states that the changes made to illustrations admittedly included subjective aspects. A good example of this was that in a pilot study the drawing of the basic form of one object, a jacket, elicited the same responses as the colored slide of the jacket. Therefore the experimenter further "abstracted" the illustration of the jacket for the main study. The main change between the two forms was that the V-neckline and the line representing the button front of the jacket were removed in the more abstracted version. Some of the responses to this new illustration were "blueprint", "back of a picture frame", "square-headed dog", "unfinished jigsaw", "headless and legless man", and "chair facing down".

Two additional studies emphasize the need for a more careful description of how stimulus materials are experimentally varied. Fonseca and Kearl (1960) and Holmes (1963) manipulated amount of detail between pairs of pictures. One picture, which will be labelled the average detail illustration, was apparently designed to evoke the naming responses expected by the experimenters and designated as the correct response. The other picture of the pair either had detail added to it or detail removed from it. The picture with added detail was described by Fonseca and Kearl as having excessive, unnecessary detail. The average detail illustration represented the object the experimenters expected the subjects to name and a second picture included other objects not essential to the comprehension of the message. All of the illustrations were line drawings. In general, the illustrations with deleted detail were simple outline drawings (detail lines within the outline were removed) while the other illustrations included detail lines inside the outline. Deletion of detail and addition of detail were two quite different operations. Fonseca and Kearl stated that additional lines were used to make one of the objects more evident, so their changes were not simple and consistent. Holmes does not describe how the illustrations used in his study were manipulated but it seems apparent that he adopted and applied similar procedures to those used by Fonseca and Kearl.

These pictures were presented to groups of subjects in test booklets and they were asked to write their interpretation of each picture in a blank beneath the picture. Fonseca and Kearl collected their data from rural young people in sections of Brazil; Holmes collected data from adults and young people in Kenya. Responses were judged to be correct if they included the expected name or synonyms of it. In most comparisons a significantly higher percentage of wrong responses were given to both the excessive detail and the deleted detail illustration in comparison with the average detail illustration.

The description of the manipulation of these pictures is misleading. When it is said that the amount of detail is manipulated it is not expected that different objects will be added or taken away from the picture with which it is compared. In one deleted detail illustration in the Fonseca and Kearl study, not only were interior lines removed but the outline of the cow was quite noticeably changed. In the Holmes study one illustration showed a man milking a cow. In the deleted version, outlines of the same figures were presented but the milk bucket was removed from the picture. The correct response was "milking a cow". The differences in the percentage of correct responses could be due to any one of these changes or to the combination of them. The language used to describe the changes in the illustrations seems poorly chosen, and the changes themselves (as determined from an inspection of the illustrations) seem to be inconsistent with the description.

All probable changes in naming responses that may result from adding or deleting elements in pictures can be listed. It may be helpful to this discussion to introduce at least some of the terminology suggested by Hunt (1962) for application to discussions of the experimental study of concept learning. Since there are some differences in Hunt's terminology as compared to the terminology used in Chapter II, these differences will be pointed out.

In accordance with Church (1958), a name is considered to have two properties. The denotation of a name is the set of objects to which the name is appropriately applied. The appropriateness of application of a name is determined by a classification rule which is defined to be the concept of the name. The concept or meaning of the name is the second property of the name. The concept is a statement of structure in the description of objects to which the name applies.

A classification rule (a concept) is stated in the terms of a set of values of dimensions which characterize objects to which the name applies. These dimensions can be any distinctions which any learner can make. They are not limited to differences such as color, size, etc., but can include dimensions such as "years of schooling", "place of birth", etc. (In a discussion of pictures, primary interest is in visually discriminable dimensions.)

The dimensions commonly used in concept learning studies are color, size, number, geometric form, etc. The type of concepts learned in these studies are "large, black squares", "small, white circles", etc. According to the terminology used in discussing the logical analysis, values of dimensions can be classified as relations and things. Most of the concepts studied in concept learning experiments have been connections of things and monadic relations which would be classified as facts. In these experiments, it was assumed that names for the different values of the dimensions used were available to the subjects and they learned the particular combination of values the experimenter had arbitrarily defined as the concept.

In addition to the above differences in terminology, there is a difference in usage of the term "concept". The main difference is that in the discussion of the analysis, "concept" is used to indicate both the name and the concept of the name. The distinction between these terms in Hunt's terminology may avoid confusion.

The above terminology will be used in discussing changes of naming responses to additions and deletions of elements in pictures. It will be assumed that presenting a picture to a subject and asking for a naming response is equivalent to saying that the picture represents to the subject a member of the set of objects comprising the denotation of the name of a concept. It is this name which is given in response to the picture.

The changes made between pictures in the experiments just reported can be grouped under two operations: the removal of elements from pictures and the addition of elements to pictures. The removal of elements from the picture will be considered first.

1. The removal of some physical elements from a picture such that the number of dimensions that apply to the object being represented are decreased can affect naming responses in several ways.

(a) Suppose the original picture had elicited a noun phrase consisting of a noun plus modifiers. It is assumed either that the language has no unique name for the hypothetical set of objects of which the object represented in the picture is interpreted to be a member, or that the subject, for some reason, did not associate the object in the picture with the appropriate name. He applied the name of a more inclusive concept, but specified a subset of the denotation of the applied name by naming the dimensions which apply to the subset, and which differentiate it from the set of objects comprising the denotation of the name which was applied. It is further assumed that when such a noun phrase is evoked, the dimensions named will be dimensions displayed in the picture. If these dimensions are removed from the picture, as was done with some of the pictures in the Fleming study, the modified picture is likely to evoke the name without modifiers.

On the other hand, it is possible that the removal of physical elements from a picture decreases the number of dimensions in such a way that the original picture and the altered picture are interpreted as representations of objects that are members of denotations of two different names. In such a case it is probable that each picture will evoke the name of the denotation of which the pictured object is interpreted to be a member.

(b) If the original picture evoked a name and the altered picture has dimensions removed that are relevant to interpreting the picture as a representation of an object that is a member of the denotation of that name, and if the remaining dimensions are ones that have not been consistently associated (are not relevant to) a set of objects comprising a denotation of a learned name, the picture may not readily evoke any naming response. Responses that do occur may vary widely among subjects and may occur with long latencies.

(c) It is possible that the dimensions removed are not relevant in determining the membership of an object in the denotation of a name. In this case, there will be no change in the naming response between the two pictures.

A similar analysis is made of changes in the interpretation of pictures resulting from the addition of elements to pictures.

2. The addition of physical elements to a picture such that the number of dimensions which apply to the object being represented are increased, can affect naming responses in several ways. Assume that the original picture reliably elicited the name of a concept.

(a) The additional dimensions or the combination of the added dimensions with the previous dimensions may be interpreted as a combination which has been consistently associated with a different set of objects comprising a different denotation and paired with a different name. This name will be evoked with high probability if such a picture is presented.

The added dimensions may not result in interpreting the representation of the object as a member of a different set of objects but it may be interpreted as a member of a subset of the original set and this may result in attaching modifiers to the name previously evoked.

(b) The added dimensions may result in a combination which is interpreted as unlikely or inconsistent with the previous experience of the subject. The result may be something like an example used by Bruner (1956) of an illustration of a man dressed in a track suit throwing, not a javelin, but a violin. The subjects' responses to these pictures will demonstrate longer latencies and greater variability of naming responses, or they may ignore some dimensions of the picture in order to make a sensible interpretation of the picture.

(c) The added dimensions may not combine with the previous dimensions, may not affect interpretation of the picture and therefore, will not result in a change in the naming response.

Several conclusions can be drawn from the above analysis. When pictures are selected and manipulated in any way other than a completely objective and predetermined one, it seems likely that the experimenter will make decisions on a subjective basis which will result in manipulating the picture so that most of the time expected results will be found. Part of the time it will be impossible to manipulate pictures to achieve the desired results. If objective mechanical changes of predetermined physical characteristics of a sample of pictures are performed and naming responses collected from "before and after" pictures it seems likely that all of the above results may be found.

The illustration of the jacket in Fleming's study illustrates two of these points. Although the experimenter produced an illustration of a jacket which was a line drawing of the basic form of a jacket, in a pilot study, it did not evoke responses more inclusive than the color photograph of a jacket. Therefore, the illustration was further abstracted by removing the V-neckline and the line down the front of the jacket (buttons). The result was that subjects gave extremely varied naming responses to the illustration. The two abstracted versions seem to be examples of (1c) and (1b) above. Apparently, the V-neckline and the line (of buttons) were relevant to interpreting the illustration as a jacket. When they were removed, the dimensions which remained were not relevant to the interpretation of a common object belonging to the denotation of the name "jacket". Since a response was required, they offered one, but the range of responses (see footnote 2 on page 37) indicate the lack of control of the stimulus object.

Fleming was attempting to evoke a more inclusive name than jacket. What are some possible names? "Outer garment", and "clothing" are two which seem most likely, but perhaps more inclusive than he intended. However, they illustrate an additional problem that affects pictures of objects which are related to names through membership in the denotation of the name. The concept of a name is defined as the description of the dimensions shared by objects included in the set of objects comprising the denotation of the name. When the description of the set of objects is not primarily in the terms of visually perceivable dimensions, the perceptual characteristics of objects comprising the denotation will be heterogeneous. It is highly improbable that a subject presented with a few objects from this denotation will respond with the name associated with the denotation. "Outer garments" and "clothing" are two names whose denotations include objects of widely varying physical characteristics. It seems impossible to prepare a picture which will reliably evoke the name "clothing" unless many representations of different articles of clothing are included in the picture.

It is suggested that emphasis ought to be placed on the name of the concept which the experimenter expects an illustration to evoke in the perceiver. The selection and manipulation of the representation of objects to evoke the desired name then becomes a useful problem. There is a need for a language in which the experimenter can describe how the illustrations were prepared so that this process can be communicated to other experimenters.

Returning to the Ryan and Schwartz study, it should be recalled that the task was quite different than that required by the other studies. The subject knew what kind of object was represented and that he had to make one of four possible discriminations. Apparently the information required to make the necessary discrimination was most efficiently presented in the cartoon form. The cartoon treatment may have presented the dimensions necessary for making a correct discrimination more clearly than the other illustrations. Therefore, the time required to scan the illustration to find the relevant information was least for this illustration. Given that the expected response is made to an illustration, the response latency might be used as a measure for selecting the most efficient illustration.

Several studies have compared learning from textual materials with learning from textual materials plus illustrations. For reasons given below, these studies will not be discussed in detail. According to review articles (Allen, 1960; University of Illinois, 1952; and Spaulding, 1955) the following studies found that the addition of illustrations facilitated learning significantly: (Halbert, 1943; Kambly, 1943; Lewerenz, 1929; Spaulding, 1953; and Strang, 1941). An almost equal number of studies did not demonstrate any difference when illustrations were added: (Goodykoontz, 1936; Miller, 1938; Stutz, 1945; and Vernon, 1954). There seem to be many possible explanations for this lack of agreement, including lack of control of influential variables and the fact that different dependent variables were used as measuring criterea. In most of the studies there was no discussion as to whether different kinds of information were presented in the illustration, or the text, or whether these two forms were redundant in terms of the information presented. The degree of redundancy or integration needs to be controlled. It is also not known whether the test items sampled the information presented in the text, or in the pictures, or both, and how much of each. If these factors are controlled it is hoped that future studies of this type will provide another kind of data to improve our understanding of learning from pictures.

Ketcham and Heath (1962) recorded on tape a description of a fictional holdup-murder followed by an arrest, trial, and execution. The narration was divided into several divisions each of which referred to and identified a picture and added information not obtainable from the picture.

Three sets of black and white slides were prepared. The first set was the set referred to above which presented information relevant to the narration. The second set were pictures of geometric forms. The third set were landscapes. The "sound only" and "sound plus one of the picture sets" constituted four treatments which were administered to four groups of from 20 to 40 students. Groups were equalized on IQ scores. A 30 item multiple choice test was given to all students following the experimental treatments. These questions did not ask about information presented in the pictures but only about information presented in the sound track. A significant difference was found among the treatments on the number of items of the test which were correct. The order, from highest to lowest scores, was "sound plus relevant pictures," "sound only," "sound plus landscapes," and "sound plus geometric forms."

Travers (1964) reports that Ketcham and Heath also prepared a film on the life and work of William Wordsworth. The narration described the life and work of Wordsworth. The visuals were English scenes of the kind which might have inspired the poems to which the narration referred. One group of students heard only the narration and another group was presented the visuals and the narration. A test of information presented only in the narration was given to all subjects. A significant difference was found favoring the group which received the narration plus visual treatment.

These two studies agree in showing a difference in recall of information received aurally between "sound only" and "sound plus visuals" favoring the latter. In neither case did the test include information presented visually. The conditions are quite different from the comparisons of "textual" and "illustration plus textual" materials. They are suggestive of procedures which ought to be applied to studies of illustrated textbooks.

Kuethe, in several experiments studying "social schemas," has utilized a technique of having subjects freely arrange cut-out figures on a felt board, or having them replace two figures on the board as accurately as possible. He has found that what he calls the subject's "social schema" affects the way they arrange and replace the figures. For example, in one study, Kuethe (1962) reports that two men cut-outs originally placed 20 inches apart on the feltboard were replaced a mean distance of 16.0 inches apart when they were facing each other and 23.2 inches apart when they were facing apart.

The technique developed by Kuethe suggests a procedure by which subjects can create pictures of a limited kind and may be especially applicable in situations where it is desirable to avoid verbal responses.

Kuethe's results can be discussed in terms of the logical analysis that was presented in Chapter II. Two male figures facing away from each other may be interpreted as a state of affairs in which a dyadic relation high in repulsion connects the figures. The replacement of the figures may be affected by the interpretation of the dyadic relation connecting the figures. If there are some non-social stimulus materials between which subjects would interpret dyadic relation of attraction or repulsion, it would be possible to contrast these two different explations of the results. This is a problem the experimenter hopes to consider in the future.

Concept learning with adult subjects

A few studies of concept learning will be discussed. There are several purposes in relating the present study to the concept learning literature although the study was not originally conceived as a concept learning study. First, the logical analysis proposed as a method of analyzing pictures gives primary emphasis to concepts as the components of a structure of pictorial information. Secondly, in contrast to the conceptualization of pictorial materials by Morris (1946) and Gibson (1954) this experimenter is interested in developing a viewpoint which discusses pictures as articulate fields which are perceived to be representations of states of affairs. Elements of the field are perceived to be representations of objects which are members of the denotation of a name. This suggests a slightly different relationship between pictures and names than other discussions of pictures have presented. This development can not be more than suggested in this report. A further purpose is to relate the results of the experimental study reported here to concept learning studies of the effect of stimulus variables on the learning of concepts. Finally, the concept learning literature seems to offer an experimental paradigm within which picture variables can be studied and from which it may be possible to generalize some results and apply them to the use of pictorial materials in practical learning problems.

Heidbreder administered a series of experiments where the main variable was groups of stimulus materials to which subjects were to learn appropriate responses. The types of groups used were labelled "concrete objects" (drawings of faces, trees, buildings), "spatial forms" (drawings of unusual, simple geometric arrangements of objects or geometric forms), "numbers" (drawings of one or more groups of objects totalling a given number of objects or geometric forms), and "color" (colors were applied to drawings of objects, forms, etc.). The procedure and types of responses required were different among the experiments. Heidbreder (1946) began her studies by using a memory drum apparatus and having subjects learn nonsense syllables in response to the stimuli. One response was appropriate to all members of the denotation of one name (e.g. all faces) and other syllables were learned to members of the denotation of other names. Heidbreder recorded the trial number after which a subject made no further incorrect responses to members of a given denotation. Significant differences were found among the mean trial numbers on which different types of names of concepts were first attained (all instances named correctly). Although many variations of the stimulus materials were tried out by Heidbreder, with some interesting differences, the general trend was for the denotation she labelled as "concrete objects" to be attained first, then "form" and lastly, "number" denotation. Heidbreder (1949) later changed to a card sorting task using cards which could be sorted into groups of three or four values on any of three or four dimensions, the dimensions being similar to the groups listed above. Subjects were asked to sort cards as they liked, but after each sort they were asked to sort again until all dimensions had been sorted. The order of sorting of dimensions was recorded. The results, in general, agreed with the orders found in the previous procedure.

The difference in the two procedures and in the dependent variables employed in these experiments is quite marked. An ordering of the dimensions used in free sorting tasks seems more related to a preference or response predilection measure than a measure of ease of attaining a concept. On the other hand, the trial number after which no instances of a concept are incorrectly named is typical of measuring procedures used for evaluating attainment of learning. (Heidbreder referred to these results as demonstrating a "dominance hierarchy of concepts".) The relationship demonstrated between these two measures suggests that ease of attaining concepts is closely related to saliency of perceptual organization if it is assumed that subjects will begin a sorting task on the dimension which is most obvious or striking (salient) to them. This suggestion can also be applied to the earlier paired-associate procedure by assuming that the subject discovers the similarities among the instances displaying the more obvious dimensions earlier, and therefore correctly names these instances earlier than others. It is also possible that these responses, which are correct for some stimuli, may be incorrectly applied to instances of other concepts which have similar perceptual properties and, therefore, interfere with correct responses to these instances.

Osgood (1953) reports that Heidbreder's data show that the range of trials between the first correct response to an instance of the denotation of a name is relatively narrow for the concrete objects but broader for form and number concepts. He interprets this difference in terms of relative availability and interference among mediators. Baum (1954) replicated Heidbreder's paired-associate concept learning procedure. He analyzed errors made by subjects and found that stimuli which were members of the denotation of the name of the concepts, which were learned more slowly, were more frequently interchanged. He related these findings to Gibson's stimulus generalization theory.

Another way of discussing these differences would be to suggest that the subject produced hypotheses for organizing the different instances of the denotation of a name. A first correct response must be an indication that a subject is using a hypothesis which is at least partially correct. That is to say, that the probability of a chance correct response is low, and since identical stimuli are not presented until after 16 trials, specific s-r associations are not being established. For the instances of the denotation described as concrete concepts, this initial hypothesis is apparently quickly shaped into one which results in correctly identifying all instances of the denotation used. The successful application of one hypothesis may bias the subject to apply similar hypotheses to instances of the denotations of names of forms or numbers, and thus interfere with the formation of correct hypotheses and responses.

In a series of experiments Grant and others have investigated the relative difficulty of sorting on different dimensions with the Wisconsin Card Sorting Test (WCST). Grant, Jones, and Tallantis (1949) found, contrary to Heidbreder, that the order of ease of sorting was number, form, and color. In these studies the correct dimension for sorting was arbitrarily determined by the experimenter and was changed after ten correct responses. The difficulty of sorting

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was measured by the total number of errors. The response of sorting for number perseverated more than was the case for form or color. Two explanations were offered for the differences between these results and those reported by Heidbreder. One was the difference in procedure in the two experiments. The WCST consisted of 64 response cards, each card being a combination of one of four values of each of three dimensions. The dimensions were number (1,2,3,4), color (red, green, blue, yellow), and form (triangle, star, circle, cross). Four stimulus cards differing from each other on all four values of each dimension were placed in the upper set of four double compartments on a sorting tray. The ordering of these cards from left to right on the number dimension was 1, 2, 3, 4. This ordering is one factor which may have facilitated the sorting on the number dimension. The subject was instructed to sort the response cards under the stimulus cards and try to get as many "right" as possible. After each response the subject was told whether the response was "right" or "wrong." One dimension was initially arbitrarily correct. After the subject had made ten correct responses, the experimenter changed the correct response to another dimension and changed the instructions ("right" or "wrong") to the subject accordingly. The "correct" response was changed after every sequence of ten correct responses.

Another explanation of the difference attributed it to the regular spatial arrangement of forms on the WCST cards. The arrangement was regular for each number but the differences in arrangement among different numbers constituted an easily discriminable dimension perfectly correlated with different values of number. A revised version of the WCST cards was produced in which the figures were printed in random spatial arrangements. Grant (1951) compared sorting responses with the two sets of cards and found the sorting for number to be more difficult with the revised cards. The verbal responses of subjects indicated usage of the systematic spatial arrangement with the earlier WCST cards.

Grant and Curran (1952) repeated the earlier experiment with the revised cards. They found form and number to be of about equal difficulty and color to be the most difficult. The perseveration of number responses was maintained with the change in the cards.

In a second group of studies, measures derived from information theory have been applied to the stimulus materials to separate the stimulus dimensions into bits of relevant and irrelevant information. Stimulus materials are constructed from a number of two-valued dimensions. The experimenter defines an instance of the denotation (a positive instance) as one value of a dimension or a combination of different dimensions. Any instance which does not contain this value or combination of values is not an instance of the denotation. (These are called negative instances). The dimensions on which one value of the dimension is associated with positive instances are called relevant dimensions. Irrelevant dimensions are those in which changes in the values of the dimension are not regularly associated with changes from positive to negative instances or vice versa. Several experiments have demonstrated that up to five bits there is a linear relation between the number of irrelevant dimensions and the difficulty of concept attainment (Bourne and Restle, 1959).

In the above experiments it was generally assumed that the difficulty of concept attainment was independent of the kind of dimension and the values of dimensions used in the experiments. Brown and Archer (1956) found that concepts having the spatial location of a stimulus as a relevant dimension proved to be more difficult than others not having spatial location as relevant. This difference was attributed to the obviousness of the information concerning spatial location.

Archer (1962) manipulated the obviousness of two different dimensions under conditions where they were both relevant and irrelevant. Obviousness was operationalized in the following ways. For the size dimension, high obviousness was related to differences in the heights of the stimulus figure from one inch to 3/4 inches. The low obvious condition had figures one inch and 7/8 inches in height. The other manipulated dimension was form. The high obvious form was related to differences between a square and a parallelogram with opposite acute angles of 84 degrees. The low obvious form had a square and a parallelogram with opposite acute angles of 87 degrees. This operation seems to relate obviousness with ease of discrimination.

Archer predicted that there would be an interaction between obviousness and relevancy. When the more obvious dimension was also relevant the concept should be easier to discover than when the dimension was less obvious. But when the more obvious dimension was irrelevant, the concept should be more difficult to discover than when the dimension was less obvious. The hypothesis was verified. A significant difference between Manipulated Dimensions, an interaction of

Manipulated Dimensions and Relevance, and a three-way interaction among Sex by Manipulated Dimension by Relevance was also found. Both sexes performed similarly when size was relevant or irrelevant. When form was relevant, men found the task easy but women found it difficult. When form was irrelevant, men found the task difficult and women found it easy.

With another sample of men and women students, Archer collected verbal descriptions of the above stimulus materials. The men labelled the two different values of form as squares and parallelograms or trapezoids. Women called them squares and nonsquares or not squares. Archer suggests that a difference in labelling ability may have affected obviousness of a dimension. He states that the women did not have distinctive labels for the different forms. In the context of the experiment it would seem that "square" and "nonsquare" are adequately distinctive labels. However, the fact that the women did not apply the label "parallelogram" to the appropriate from suggests a lack of previous experience with these forms. The inability to apply the correct label may be only a symptom of a more basic lack of exposure to these kinds of forms.

Archer's study seems to relate to the work of Heidbreder and Grant. It suggests that at least part of the difference in difficulty of learning different concepts may be explained by a factor of ease of discriminating among the values of the dimensions used. The demonstrated difference between sexes suggests an additional factor, the nature of which, is not clear.

The majority of concept learning studies have manipulated very limited aspects of the stimulus dimensions. Shepart, Hovland, and Jenkins (1961) organized four different sets of stimulus materials which were described as two-valued, three dimension stimuli. Each set contained eight stimuli and they were divided into all partitions of four stimuli. Six types of division were possible. (Seventy divisions were possible but could be transformed into six by redefining the dimensions). One set of stimuli used in this experiment was geometric forms which varied in two values of size, form, and color. These dimensions are identified in Table 5 and are used in the following discussion to illustrate the six different divisions of one set of stimulus materials.

Table 5

Dimensions and Values of the Shepard et al (1961)
Stimulus Materials

	Dimensions		
	Size	Form	Color
Values	L (large) l (small)	T (triangle) S (square)	W (white) B (black)

The six types of divisions of the stimulus materials are as follows:

Type I. Each stimulus in a subset of the partition has a common value on one relevant dimension. The difference between subsets is that the value of the common relevant dimension is different. For example,

(WTL WTl WSL WSl)
(BTL BTl BSL BSl)

Type II. Each stimulus in a subset of the partition has either common values on each of two relevant dimensions or it has neither of these values of the relevant dimensions. The difference between subsets is that the value of one of the relevant dimensions is different for corresponding stimuli. For example,

(WLS WLT BlS BlT)
(WlS WlT BLS BLT)

Type III. A pair of stimuli in a subset of the partition has common specified values on each of two dimensions. A second pair has common specified values on each of two dimensions. One dimension will be relevant to both pairs but have different values in each pair. The other dimension will be different for each pair. The difference between subsets is that the value of one of the dimensions shared by corresponding pairs of stimuli is changed. For example,

(WTl WTL BSL BTL)
(WSl WSL BSl BTl)

Type IV. Three stimuli in a subset of the partition share a common value on a particular dimension. A fourth stimulus is arbitratily chosen with the condition that it does not share this common value. The difference between subsets is that the value of the particular dimension shared by the three stimuli is changed. In addition the arbitrary stimulus must be the complement of its corresponding stimulus in the other subset. For example,

(WTL WTl WSl BTl)
(BTL BSL BSl WSL)

Type V. The division of stimuli in a set are the same as in Type IV except that the corresponding arbitrary stimuli differ in value on only one dimension instead of all three. For example,

(WTL WSL WSl BTl)
(BTL BSL BSl WTl)

Type VI. There is one partition of the eight stimuli to which no abstract rules, in terms of dimensions and values, of assignment can be applied. It is,

(BTL BSl WTl WSl)
(BTl BSL WSl WTL)

Shepard et al used the above types of stimulus groupings in a paired-associate experiment where one response was learned to stimuli of each subset of the partition. In a second study all eight stimuli were presented simultaneously. In one condition of the second study, subjects were given one minute to develop a rule for categorizing the stimuli. In the other condition, they were to memorize the sorting that was presented. Criterion measures of all these tasks were highly correlated and they all agreed on an ordering of difficulty according to concept types which was from easiest to most difficult; Type I, II, (III, IV, V), and VI. With practice, subjects were able to learn Type VI concepts with less difficulty.

If the previous experiments are compared to these types of concepts, it appears that most of them fit into or are very similar to Type I concepts. If it is necessary to consider all the possible ways of combining stimulus materials into denotations of names, then it appears that only a small beginning has been made in experimental work. It is an interesting question to speculate whether these types have counterparts in the realm of "real world concepts." Even if there are concepts similar to Type IV or V it is doubtful that they would be taught without pointing out the classification rule and the exceptions to it. This is not a criticism of the experiment but one wonders if knowledge useful to the practitioner would not be accumulated more quickly if the laboratory experimenter occassionally related his research direction toward significant practical problems.

In this respect it is an interesting experience to reread Hull's (1920) classical study of concept learning. The conclusions are suspect since the criterion for determining a difference seems to be nothing more than a discriminable difference between two curves. It is the choice of variables to be manipulated and the relations drawn between these variables and parctical learning problems that are of interest. The development of these relations and the testing of them in experimental situations ought to be the goal for at least some experimenters.

A comparison of the kinds of concepts studied in the experimental literature with Wittgenstein's analysis is not particularly helpful. Wittgenstein analyzed the structure of fields of information as they are encountered in presentations of meaningful information. The majority of the concept learning experiments have been an extension of interest on the part of experimenters in discrimination learning. They have continued to use the kinds of stimulus materials which were useful in discrimination studies and which permit relating the results of concept learning experiments to discrimination learning. The dimensions which have been manipulated as stimulus variables seem to have been chosen primarily because they are convenient.

Two observations seem pertinent. The first concurs with the conclusions from the Shepard et al study; namely, concept learning experimenters have been concerned with a very limited range of forms of concepts. The kinds of concepts which have been studied, in Wittgenstein's terms, have been of the category of facts consisting of connections of one thing and monadic predicates. (Number concepts are not included.) Concepts involving relations between more than one thing seem to be an especially neglected type of concept which ought to be studied.

The other comment is an appeal for studies using what Hunt calls "thematic materials". Hunt (1962) objects to the use of thematic materials primarily because it is very difficult to know to what dimensions of the stimulus subjects are attending.

Some of the problems to which Hunt alludes are demonstrated in a study reported by Bruner, Goodman, and Austin (1956). Two sets of carefully controlled stimuli, one composed of the traditional color, form, size, and border dimensions, and the other matched in some respects to the first set of materials but of a thematic nature were compared. The "abstract" materials were cards on which were a large and a small geometric figure. Both figures could have two values on three dimensions (form, color, and border). The "thematic" materials were like the abstract in presenting a large figure (an adult figure) and a small figure (a child figure) which could have two values on three dimensions. Some of the dimensions and values were the same for both adults and children. These were sex (male and female) and type of clothing (day dress and night dress). The remaining difference for the adult was "smiling and giving a gift" or "frowning with arms clasped behind the back." The corresponding difference for the child figure was "smiling and holding out the hands" or "looking down with hands behind the back."

The procedure was to display the 64 cards in these sets before the subjects and to present a focus card which was a member of the denotation to be learned. The subject was told to choose cards from the display. Each choice was evaluated by the experimenter by telling the subject "correct" or "incorrect". The subject was told to attain the concept with as few choices as possible. (The term "concept attainment" as used here is equivalent to Hunt's "denotation learning" notation.) There was a significant difference between the number of choices required to criterion. The abstract group made 6.1 choices compared to 9.7 for the thematic group. The abstract group offered an average of 0.5 incorrect hypotheses while the thematic group offered 1.9. Subjects in the thematic group tended to change values of dimensions differentially. More changes were made of the clothing dimension and least of the sex dimension, especially of the adult figure. Bruner et al speculated that this latter finding indicates that the adult figure is the chief protagonist and that the sex of the figure is important to the theme. Subjects apparently constructed stories about the focus card in which the adult figure was the subject of the story. They tended to change other parts of the story more often than the subject. Similar differences were not found in the abstract group.

The learning psychologist who is interested in discovering relationships among parameters of the learning situation uncontaminated by the previous learning history of subjects will avoid stimulus materials of this kind. Experimenters interested in communication problems need to find ways to account for previous learning histories, especially if they are fairly similar for groups of subjects. Knowledge of these factors may be very important for the design of effective materials. Although Hunt suggests that thematic materials be used for specific purposes only, an interest in the communication of information requires the use of thematic materials. Procedures need to be developed to obtain independent measures of relevant parameters of pictorial stimulus materials so that these parameters can be equated or controlled and then it will be possible to compare studies using different stimulus materials.

The procedure for obtaining a measure of complexity of a stimulus which seems applicable to a wide range of stimulus materials (although such applications have not as yet been reported) was developed by Glanzer and Clark (1962). The procedure is simply to require subjects to write short, but accurate, descriptions of the stimuli so that they would be able to use these verbal descriptions to reproduce the stimulus materials.[3]

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[3] In the experiment where this technique was employed, reproduction consisted in marking in one of eight form outlines a B if that form had been black, and a W if it had been white.

This measure was employed in a perceptual recall task of the color of each of a series of eight abstract forms. The eight forms were presented simultaneously and in a row of fixed order. The color variable had two values, black or white. A reproduction measure and a discrimination measure of accuracy of recall were obtained for the set of stimulus objects. It was assumed that these measures were measures of stimulus complexity. The correlation between these two measures for each matched pair was .677. A partial explanation for the low correlation was the fact that the reliability coefficient of the discrimination measure between two groups of subjects on corresponding pairs of stimuli was .765.

Glanzer and Clark derived measures of stimulus complexity from Gestalt principles, and from information theory, and correlated these measures with their observed measures of accuracy of recall. They also advanced a "verbal loop hypothesis" which predicts that a subject will translate visual information into a series of words and that this verbal representation controls further responses. From this hypothesis, stimulus complexity was operationally defined as the number of words in the verbal response. Glanzer and Clark collected verbal responses from subjects to the same stimuli that had previously been tested for accuracy of recall. The correlation between the mean number of words and the accuracy of recall scores of the reproduction method for 65 arrays was .826. The highest correlation found between the same accuracy of recall scores and other derived measures of complexity was .739.

It is surprising that such a simple measure as the number of words correlated with accuracy scores better than rather sophisticated measures derived from various sources. It is to be expected that this measure can be refined, and that refinements will be required as the type of stimulus materials are varied. Some possible directions that seem likely, from consideration of Wittgenstein's analysis of informational fields, is the number of names listed rather than a gross count of words. It may be that the form of a concept will affect complexity and some kind of weighing procedure will improve the fit of predicted versus observed measures of complexity.

Although the procedure in which these date were collected was not a concept learning paradigm, the application of the technique to concept learning experiments seems obvious. One intriguing comparison which the experimenter can not help making, although it is of very questionable value, is the difference in the length of the verbal descriptions of the manipulated variables between the abstract and the thematic stimulus materials in the Bruner[7] et al experiment. Is it possible to develop thematic materials which can be identified with short verbal phrases and would the results of these materials be more nearly like those obtained from the abstract materials? Such a finding would add further evidence to the suggestion of the importance of the length of the statement of the classification role.

Studies of the developmental aspects of cognition

This experimenter does not entertain any delusions of expertise in the area of cognitive development. In proposing the study to be reported in Chapter IV, the decision was made to use developmental differences in ability as a variable in demonstrating that measures of difficulty of denotation learning between two forms of concepts will change differentially among subjects of different age levels.[4] If such a difference were to be demonstrated, it suggests the need for further studies with concepts of different form, and also suggests that when concepts of different form are included in a study, some method of assessing or controlling for possible differential effects is necessary.

Three age levels from which subjects were sampled were chosen to correspond with three of Piaget's stages of intellectual development. Piaget (1960) has organized what is perhaps the most comprehensive description of the process of intellectual development. Stages of development are related to chronological age and characterized by the kind of behavior which appears at each stage. A very brief listing of some of the behavioral changes described by Piaget will be given as a framework for discussing the experimental studies to be presented. The youngest group of subjects in the study to be reported were first graders. They would belong in the upper end of the intuitive phase (ages 4 to 7) of the stage of preoperational thought (Piaget, 1960). During this stage, the child is dominated by perceptions; but the ability to think in terms of classes, to see relationships, and to handle number concepts are said to develop. This age child is supposedly limited to categorizing objects which can be described as having several dimensions, on the basis of one dimension at a time.

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[4] Denotation learning as defined by Hunt (1962) differs from concept learning in that subjects do not describe the concept but indicate an ability to discriminate between members and nonmembers of the denotation of the name of the concept.

The ages of 7 to 11 are the approximate boundaries for the stage of concrete operations. The middle group of subjects in the study to be reported were fourth graders. The ages of these children fall in the middle of the stage of concrete operations. Abilities relevant to this discussion, which are said to develop during this stage, are the ability to group objects into classes, and the ability to arrange items in an order. The abilities necessary for recognizing that two quantities are equal, even though the objects compared are perceptually not alike, develop during this stage. This phenomenon is called "conservation" and will be discussed later.

The final stage of Piaget's developmental description is the stage of formal operations coinciding with the ages of 11 to 15 years. This stage is characterized by Flavel (1963) as the stage of development in the child, when he begins to consider all possible relations supported by data and attempts to find out which of these relations hold true through logical analysis and experimentation. The third group of subjects included in the study were eighth graders. Their ages are near the middle of the age range for the stage of formal operations.

The experimenter knows of no studies that are reasonably similar to the one to be reported. Examples of different types of studies will be reported in an attempt to describe intellectual developmental in terms of the results of these studies. Relatively few comments will be made concerning these studies. Relationships between these studies and the experimental study to be reported will be made in the discussion section of the report of the experiment.

Thompson (1941) reported that 60 per cent of a group of 60 students, 10 from each of the first six grades, sorted the 12 figures of the Weigl Color-Form Test on one dimension. Forty per cent of the subjects sorted on both dimensions. Significantly more of the older subjects (grades 4 to 6) sorted on two dimensions than did the younger subjects (grades 1 through 3). The ages of these children were not given and the age span within each group was unfortunately broad. The median age for the younger group is estimated to be about 8 and the older group 11 years. The children were asked to explain the basis of their categorizing of the Weigl figures. Only 50 per cent of the responses could be classified as "generalizations" (responses mentioning form, shape, or color). Generalizations were offered more frequently by older than younger children, but it is not clear if this difference was significant. These date roughly correspond to Piaget's description of the development of categorizing behavior on one and two dimensions.

Berlyne (1963) describes some experiments by Luria in which children of different ages were stimulated by a red light and a green light. The children were given a rubber bulb which was held in one hand. If the experimenter said, "Press the bulb when the red light comes on, but do not press if the green light comes on," children below the age of 3 years pressed immediately and stopped pressing when the light came on. After the age of 3 the children pressed the bulb when the light came on, but did not discriminate between the red or green light. From 5½ or 6 and older, a child was able to respond according to the directions.

The finding of quite similar behavior by Paramonova with this same apparatus is also reported by Berlyne (1963). In these experiments very simple verbal instructions were used. When the red light came on, the experimenter said, "Press." At the onset of the green light, the experimenter said, "Don't press." The children learned to respond appropriately and to anticipate the experimenter's verbal commands. After several trials, the experimenter began verbalizing after the child responded. If the response was appropriate, he said "Correct." If the subject pressed inappropriately, the experimenter said, "You shouldn't have pressed," and if the subject failed to press when he should have, the experimenter said, "You should have pressed."

After a number of trials, Paramonova changed the procedure by requiring the subject to respond to the onset of the light to which he previously did not respond and vice versa. Within a trial or two, older children reversed responses and continued making consistently correct responses. Three year-old subjects initially responded to both lights. The response to the negative stimulus disappeared very slowly. Reversal training took some time for these subjects and conditioning was very unstable.

The similarity of the behavior of subjects between these two different procedures suggest that failure of the 3 year-olds to respond according to the directions in the Luria study may not have been due to a lack of ability to understand the verbal instructions but to a lack of ability to make the appropriate responses, or perhaps both.

By interpolation, the results suggest that, without specific training, children were able to discriminate and respond differentially to two values (red and green) of the color dimension at the age of about 6 years. Six years of age is about the middle of the intuitive phase in which children are supposed to be able to categorize on one dimension.

Church (1961) suggests that young children's performance on sorting tasks is not based on an abstraction of one dimension of an object, but on some recognition of global perceptual similarities. Two different age groups may respond quite similarly on a sorting task. The younger subjects may be sorting on the basis of global perceptual similarities while the older subjects have abstracted a dimension and sort on the basis of this dimension.

Some evidence to support this difference will be reported from the Colby and Robertson study where younger subjects did not consistently match objects on the same dimension. Differences in verbal explanations of sorting behavior might be another indication of these differences in conceptual development.

Thompson's (1941) subjects were also asked to solve the Vigotsky Test of Concept Formation. This test consists of 22 wooden blocks of different color, top surface area, form, and height. The subject was told that there were four different kinds of blocks, that each kind had a different name, and that his task was to find the four kinds and put them into separate corners. The experimenter picked up one of the blocks, showed the subject the name written on the bottom of the block, and put it in one corner of the board. The subject was told to put all the blocks that he thought belonged with this block, in the same corner with the first block. After he had responded, the experimenter picked up a block that the subject had incorrectly classified and showed the subject that it did not have the correct name. The subject was told to try a different way of sorting. After each sorting, the above procedure was repeated until the subject was able to form the one correct partition of the 22 blocks into four subsets.. The description of the correct subsets were: tall, large figures; flat, large figures; tall, small figures; and flat, small figures.

This task was too difficult for these subjects. One-third of the subjects tried only one hypothesis; one-third tried two hypotheses; and one-third tried more than two hypotheses. Younger subjects were unable to shift from one method of approach to another. Even with additional help from the experimenter, only four of the 60 subjects were able to state satisfactorily the generalized principle underlying solution of the task. Three of these four were in the older group. This test is difficult for several reasons. Not only must the objects be grouped according to two dimensions, but only one partition of the blocks results in an acceptable performance. In addition to this, color and form are irrelevant dimensions and other studies (e.g., Heidbreder, 1946) have shown that these two dimensions are ones which subjects will use at the beginning of sorting tasks. The experimenter reported that the subjects, when asked to explain the basis of their sorting, often used the term "size." It is not clear whether this indicates that subjects were combining two dimensions, or whether they lacked specific names and used "size" to refer to several dimensions.

A study of the dominance of color or form by Colby and Robertson (1942) presents much interesting data, but the method of tabulating the data makes interpretation of some of the results difficult. The subjects were 158 children from pre-school, first, and second grades. A "reaction field" consisting of eight colored geometric figures on a black background was placed before the subjects. Below the reaction field was a stimulus card with one colored geometric figure on it. The subject was asked, as the experimenter pointed to the stimulus card, "Is there another just like that?" The spatial location of figures on the reaction field was rotated. The figures on the field were such that in a series of 48 trials the number of correct matches presented was equalized for color alone matches, form alone matches, and "identity" (color and form) matches. Subjects were classified as "pure dominant" if 90 to 100 per cent of their choices were consistently made in terms of the same dimension. "Mixed dominant" subjects were those who favored one dimension on from 60 to 90 per cent of their choices. Subjects who alternated, giving 50 to 60 per cent of their responses to one dimension, were called "low dominant" subjects. Among the youngest subjects (3.5 to 4.5 years), the highest percentage of subjects were classified as mixed dominant (66 per cent). About an equal percentage of subjects were form dominant (11 per cent) and color dominant (17 per cent). Very few were low dominant, and low dominant remained at this level (about 3 per cent) for all age groups. As the age of the subjects increased, the trend was for mixed dominant to decrease (5 per cent) and for pure dominant form responses to increase. In the oldest group (8 to 10 years), 85 per cent of the subjects were consistently responding on the basis of form matches.

The majority of the younger subjects alternated their choices between color and form matches. On at least 60 per cent of the choices, they matched on one of these dimensions. Eighty-five per cent of the older subjects consistently matched on the form dimension.

The above data is not the complete discription of the results. Colby and Robertson tabulated identity matches in three categories: as form matches, as color matches, and as identity matches. The above percentages are confounded by this method of tabulating the data. The average percentage of responses that were classified as identity responses increased from 57 per cent for the group of 3.5 to 4 year olds, to 91 per cent for 9 year olds.[5] At all ages, more identity responses were made by subjects in the pure dominant category than in other categories. The number of identity responses for the youngest subjects seem high. This data does not necessarily support the interpretation that half of the youngest subjects were matching on the basis of two dimensions. Suppose a hypothetical subject is consistently matching on the form dimension. He scans the reaction field and points to the first object of the same form as the stimulus figure. On many trials there are two figures that are the same on the basis of form: the form matching figure, and the identity matching figure. The probability is that about 50 per cent of the choices of this hypothetical subject would be identity matching figures. Therefore, the

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[5] Recall that the report does not state that all three types of matching responses are available on each trial. It is stated that the oldest subjects rejected all responses other than identity matches. There was apparently a difference over ages of nonresponses which also confounds the data.

57 per cent identity matches reported, could have been the result of the performance of subjects matching on one dimension. The argument can be extended to include performance based on global perceptual similarities.

It was reported that the average latency of the low dominance responses was nine seconds, the mixed dominance responses was 4.5 seconds, and the pure dominance responses was 3.5 seconds. These response types are confounded with age so it is difficult to interpret the significance of these latency differences.

The results of this experiment illustrate how matching to sample responses develop over the age span of from 3.5 to 10 years. In the beginning responses are slow. It is assumed that matching is on the basis of one dimension although consistency is low. The older subjects responded more quickly and matched on two dimensions. It is impossible, from this data to describe intervening stages of response patterns because matching responses on the basis of one dimension are not reported separately from identity responses.

Among the numerous studies concerned with the learning of concepts composed of combinations of values of various simple physical dimensions of objects, there are a few which used meaningful materials. Sigel (1953) prepared a set of 25 toys or models of objects which were familiar to children (figures of people, articles of furniture, vehicles, and figures of animals). A set of 25 black and white photographs was prepared from the set of toys. The names of the objects were also printed on a set of cards.

Five sorting tasks were administered to 20 white boys of average intelligence of ages 7, 9, and 11 (20 in each age level.) Three of the sorting tasks involved the above listed three sets of materials. On one task with the toy objects, subjects could sort by manipulating the toys. In the other task they pointed and the experimenter arranged the objects. The fifth task used a list of all objects on one sheet of paper and the subjects responded by writing the names which they grouped together in lists on the bottom half of the paper.

Subjects were asked to identify each object. Then the objects were placed on the table, and the subject was told to group things that belonged together. He was asked to verbalize the reasons for grouping. All five tests were given to each subject, one per day. The order of administering tests was systematically controlled.

After one grouping was completed, the subject was asked to group again, but to try and use fewer groups. The experimenter formed several groups and asked the child to explain the basis of the groupings. These tests were called recognition tests. The order of presentation of these groupings was as follows:

1. animal figures
2. human figures
3. vehicles
4. articles of furniture
5. living things
6. nonliving things
7. all objects
8. red objects
9. metal objects

All subjects were presented the first four groups. After that, the procedure was apparently terminated with the grouping for which the subject was unable to offer an explanation.

The explanations were classified into many categories. Only the main categories will be discussed here. They were perceptual, conceptual, and miscellaneous. Conceptual groupings were those in which variation in structure and function were ignored and objects were grouped as members of a class to which the subjects could apply a name. Perceptual groupings were those representing structural, functional, or locational similarities of objects. The most interesting of the miscellaneous groupings was one where perceptual and conceptual characteristics were combined. This category is called Mixed I.

An analysis of variance was applied to scores of the number of objects subject placed in each category. No significant difference was found among the five tests (Sigel, 1954). There was a difference among ages in the number of objects placed in conceptual categories. The number of objects placed in the conceptual category increased with age. The number of objects placed in perceptual categories was significantly higher for seven year olds than for nine and eleven year olds. The number of objects placed in the perceptual and miscellaneous categories decreased with age except the category Mixed I. The number of objects placed in the Mixed I category increased between the seven to nine year olds, but decreased from nine to eleven year olds. As noted above, this category consisted of statements which used a mixture of perceptual and conceptual characteristics in explaining the basis of grouping.

Sigel noted that, in general, the physical properties of the objects, as such, were ignored, and objects were grouped according to "the meaning of the object." This apparently means that the most obvious characteristic of the object was the name of the denotation of which the object was percieved to be a member.

In the recognition tests, 40 per cent or more of the subjects from the youngest age group (seven years) identified the grouping of animal figures, human figures, and articles of furniture. By age eleven, these three groupings were identified by at least 90 per cent of all subjects. No seven year old subject identified the metalic grouping and only five per cent recognized "redness" as the basis for the grouping of red objects. Only 10 per cent of the 11 year old subjects identified these two groupings. Part of the poor recognition of the red and metalic groupings may be due to the development of a set resulting from the preceeding groupings which were quite different, conceptually, from these two.

Bruner (1964) reported a study of Oliver's where children from age 6 to age 14 sorted pictures of objects into groups that were alike. The groups of sorted objects were classified by the experimenter as complexes or superordinate concepts. Complexes were groupings where objects were included in the group according to a rule that did not account uniformly for the inclusion of all the members. In the superordinate concept groups, one universal rule did account for all objects included in the group. The six year old subjects were about equally divided into these two types of categories, but with increasing age, the percentage of complexes decreased to nearly zero while the percentage of superordinate concepts increased to nearly 100 per cent.

A Piagetian concept which has stimulated a large number of research studies is the concept of conservation. Wallach (1963, p. 246) defines conservation as referring to "the understanding that no change has occurred regarding one or more aspects of an object or a relationship, despite change in other perceivable features." The properties to which conservation has been applied experimentally (except for the conservation of the existence of objects) are all concepts of measurement (length, amount, weight, volume, area, horizontality of a liquid, number, duration, and fullness). Before conservation is achieved, a subject will report that a clay ball that has been rolled into a sausage is "more" bacause it is longer, or is "less" because it is thinner. Most of the experimental studies of conservation were replications of Piaget's original experiments and were done to verify his findings. Flavel (1963) reports that Piaget's subjects achieved conservation of matter at 8-10 years, weight at 10-12 years, and volume only at 12 years and older. Bruner (1964) reports several conservation experiments where the subject's performance was carefully analyzed to gain understanding of changes in performance. One of these studies was of the conservation of volume. Frank tested subjects from four to seven years of age. Two identical beakers were part filled with an equal amount of water. The water in one beaker was then poured into a taller, thinner beaker. The subjects were asked whether the two beakers contained the same amount of water or if one contained more water. None of the 4 year olds, 20 per cent of the 5 year olds, and 50 per cent of the 6 and 7 year olds reported that the amount of water was the same.

In the second part of the experiment, the two identical beakers equally part filled with water and a third empty beaker, wider and of the same height as the identical beakers, were all placed before the subjects. A screen was placed between the beakers and the subjects that allowed the subjects to see only the tops of the beakers. The experimenter poured the water from one of the identical beakers into the wider beaker. Without removing the screen, the subjects were asked, "Which has more to drink?" Fifty per cent of the 4 year olds, 90 per cent of the 5 year olds, and 100 per cent of the 6 and 7 year olds reported that the amount of the water was the same.

The experimenter removed the screen and repeated the question. As in the initial test, none of the 4 year olds reported the same amount of water, but only a few 5 year olds and none of the 6 and 7 year olds changed their opinion.

After an interval of 15 minutes, the first part of the experiment was repeated. Once again none of the 4 year olds reported the same amount of water. Seventy per cent of the 5 year olds and 90 per cent of the 6 and 7 year olds reported that the amount of water was the same. The change in performance from pre-test to post-test indicates that roughly 50 per cent of the 5, 6 and 7 year olds moved from not exhibiting conservation to exhibiting it. The 4 year olds were not affected by this experience and continued not to exhibit conservation.

A few studies have observed children's responses to pictures. Stern (1924) reported that his children passed through three stages in which their verbal responses to pictures were qualitatively different. These were described as a stage in which only the objects (one or more) represented in the picture were named, a stage in which the objects and actions represented were named, and a stage in which the verbal response indicated an awareness that the picture represented certain relationships combining certain objects.

Hunton (1951) recorded verbal responses of 60 children between the ages of 2 to 14 to a sample of 72 pictures. The pictures were presented to the subjects in several sittings. As the picture was presented, two questions were asked. "Who (what) is that?" "What is he (she, it) doing?" The verbal responses of the subjects were recorded. Stern's three stages of descriptions of pictures were used as categories to which verbal responses were assigned. That is, if a subject named only objects in the picture, the response was assigned to the category corresponding to Stern's first stage of description of pictures.

Children from the ages of two to three gave a high percentage of responses naming only objects represented in the pictures. From the ages of four to seven, 20 to 30 per cent of all responses were categorized as naming only objects, but about 60 per cent of the responses of this age group named objects and relations. After seven years of age, the responses naming objects and relations continued to increase. The other two categories continue to decrease. The category of responses naming objects and actions included from 10 to 20 per cent of the responses at all age groups.[6]

A set of 10 pictures was prepared as stimulus materials to be used in a projective test with young children (Amen, 1941). Verbal responses to the pictures were obtained from a sample of 77 normal preschool children. As each picture was presented, the experimenter made one or more of the following remarks:

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[6] An analysis of examples which Stern classified in his second stage (objects and actions) shows that they also include relations. Hunton may have so classified them and therefore found few responses which fitted this second stage of development.

1. "What is the story about?"
2. "What does it make you think of?"
3. "Let's tell a story about the picture!"

The children's verbal responses were classified in one of three categories. The category of Object Responses included responses that did nothing more than name or identify objects represented in the picture. Activity Response was the category that included descriptions of the pictures in terms of overt activity. The category of Inner Activity Response were responses that included inferences as to psychological states or inner activity of the persons represented in the picture. Table 6 gives the mean percentage of total responses that were classified in these three response categories for each of three age groups.

It is presumed that these pictures were selected to elicit responses infering psychological states. The pictures cannot be compared with Hunton's pictures since the latter were not reproduced.. The categories used in these two studies are somewhat different. The Activity Response category in Amen's experiment seems to include two categories used by Hunton (object and action, and object and relation categories). Both of these studies agree in finding a large drop in simple, object naming responses between ages 2 and 3 and a correspondingly large increase in the more complex responses. In Hunton's system of categories, the increase was in the object plus relation responses. The increase reported by Amen in the percentage of responses about inferred psychological states cannot be compared with Hunton's study.

Table 6

Mean Percentage of Responses of Each Age Group

Assigned to Three Categories of Responses

Response type	Age of subjects		
	2 years	3 years	4 years
Object	73	38	23
Activity	26	50	51
Inner activity	1	12	25

CHAPTER IV

EXPERIMENTAL STUDY

Method

Experimental design. The experiment that was conducted required subjects to perform a "matching to sample" task. Each subject was shown ten consecutive stimulus sets, each set consisting of a sample picture together with four matching pictures. The subject was instructed that he was to choose, from each set, the one of the four matching pictures that was similar to the sample picture. Three independent variables were each two-valued: (1) the nature of the pictorial similarity on the basis of which a subject was informed whether a choice was correct, (2) whether the sample pictures were drawn in two- or three-dimensional fashion, and (3) whether the matching pictures were drawn in two- or three-dimensional fashion. These variables were combined factorially with level of grade in school, of which there were three values, as well as with blocks of two trials, of which there were five values. The result was a 3 x 2 x 2 x 2 x 5 factorial design, with repeated measures over the five-level factor. The dependent variable was the number of incorrect choices.

Subjects. Data were collected at four of twelve elementary schools and two of three junior high schools in Bloomington, Indiana. The sample of schools was an arbitrary one. Subjects were sampled from the first, fourth, and eighth grades. Eighty subjects were obtained from each grade level. In the elementary schools, 20 subjects were randomly selected from each grade level of each school. Subjects were selected from a numbered list of all students in a grade by using a table of random numbers. Alternates were prepared in a similar manner to substitute for any subject unavailable at his scheduled time. The members in each sample were assigned randomly, in equal numbers, to the eight treatments. Forty subjects were selected in the same way from the eighth grade of each of two junior high schools.

In addition to sampling considerations, another basis for selecting small samples from several schools was the desire to reduce the possibility of communication about the experiment between subjects measured at different times. In the elementary schools there were two classrooms of each grade. An average of 10 subjects were sampled from each room; thus, one room could be tested in less than half a day. There was no evidence of communication about the experiment among the subjects.

Stimulus materials. A stimulus set consisted of five pictures which were copied on one 2 x 2 slide. Figs. 3 through 6 are examples of picture sets. One of the five pictures was in the center of the slide. It was designated the sample picture. Each of the four other pictures was placed in one of the corners of the slide. These were designated the matching pictures. None of the matching pictures were identical to the sample picture, but all of the matching pictures were like the sample picture in ways which will be explained.

All pictures were representations of two standing figures on a plain black background. One way in which pictures varied was in the pair of figure-types included in the picture. Four figure-types were used: a "man," a "woman," a "boy," and a "girl." All possible pairs of the four figure-types defined the series of ten sample pictures. These were man-man, man-boy, man-girl, man-woman, woman-woman, woman-boy, woman-girl, boy-boy, girl-girl. The left-right position of a figure was not controlled.

Since each picture was individually drawn, the figure-types in each picture were not identical. As can be seen from the reproductions included in this report, each figure-type was easily discriminable from the others. Each figure-type differed from the others in several ways. The most noticeable were differences in height, clothing, hair, and body shape.

A second way in which pictures varied was in the direction a figure was facing. Any figure could be drawn in one of four 90° rotations: facing out of the picture, facing to the left, facing into the plane of the picture, and facing to the right. There were 16 possible sets of different facing arrangements of the two figures. Ten of these combinations were used. The choice of combinations used was left to the artist's discretion.

One of the factors of the experiment was the nature of the similarity between the sample and the matching picture on the basis of which a subject was informed whether a choice of a matching picture was correct. This factor was called the Response Type. The two levels of this factor were called the Object Response and the Relation Response.

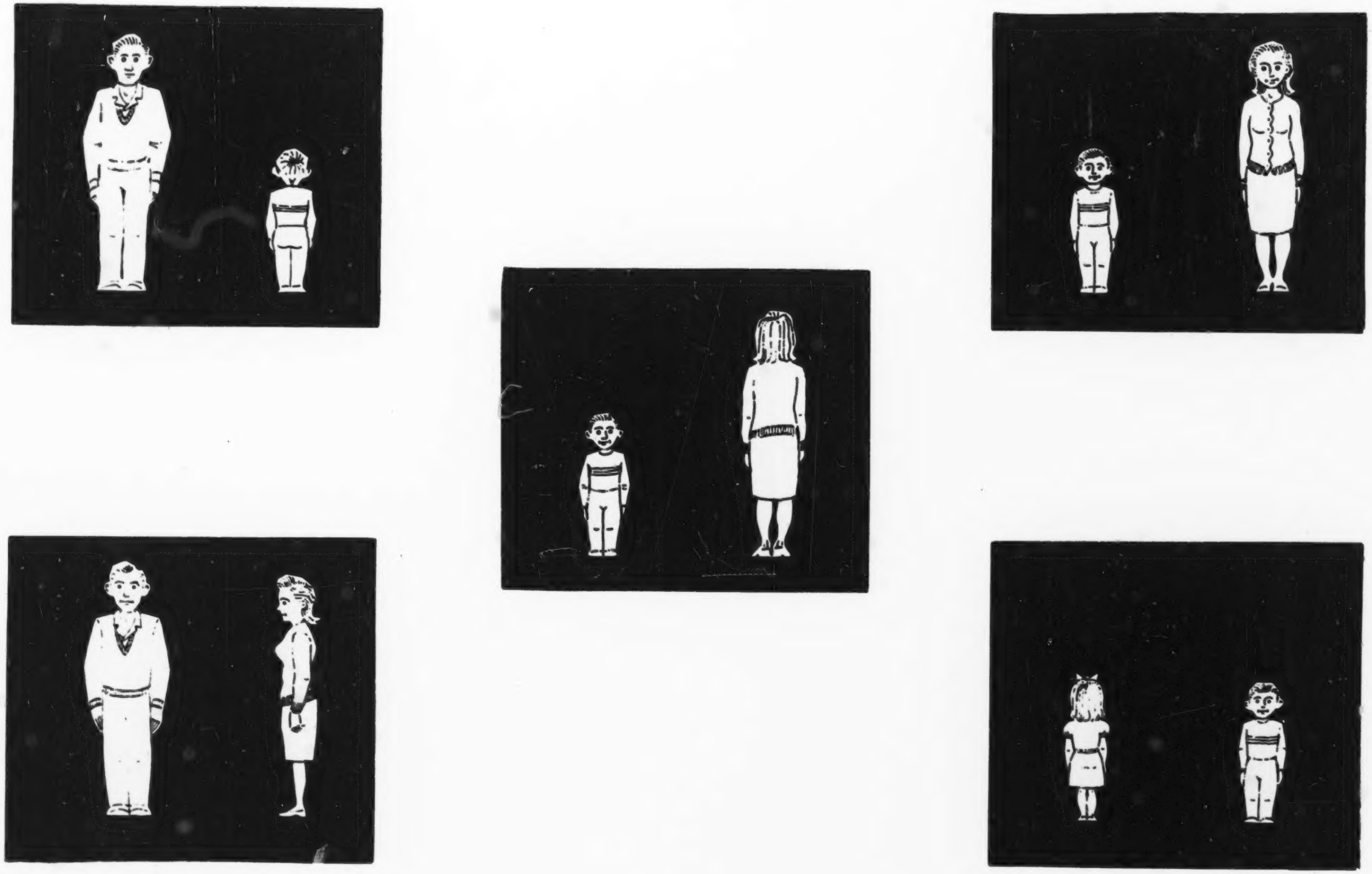

Fig. 3 An example of a 2D sample picture and 2D matching picture set

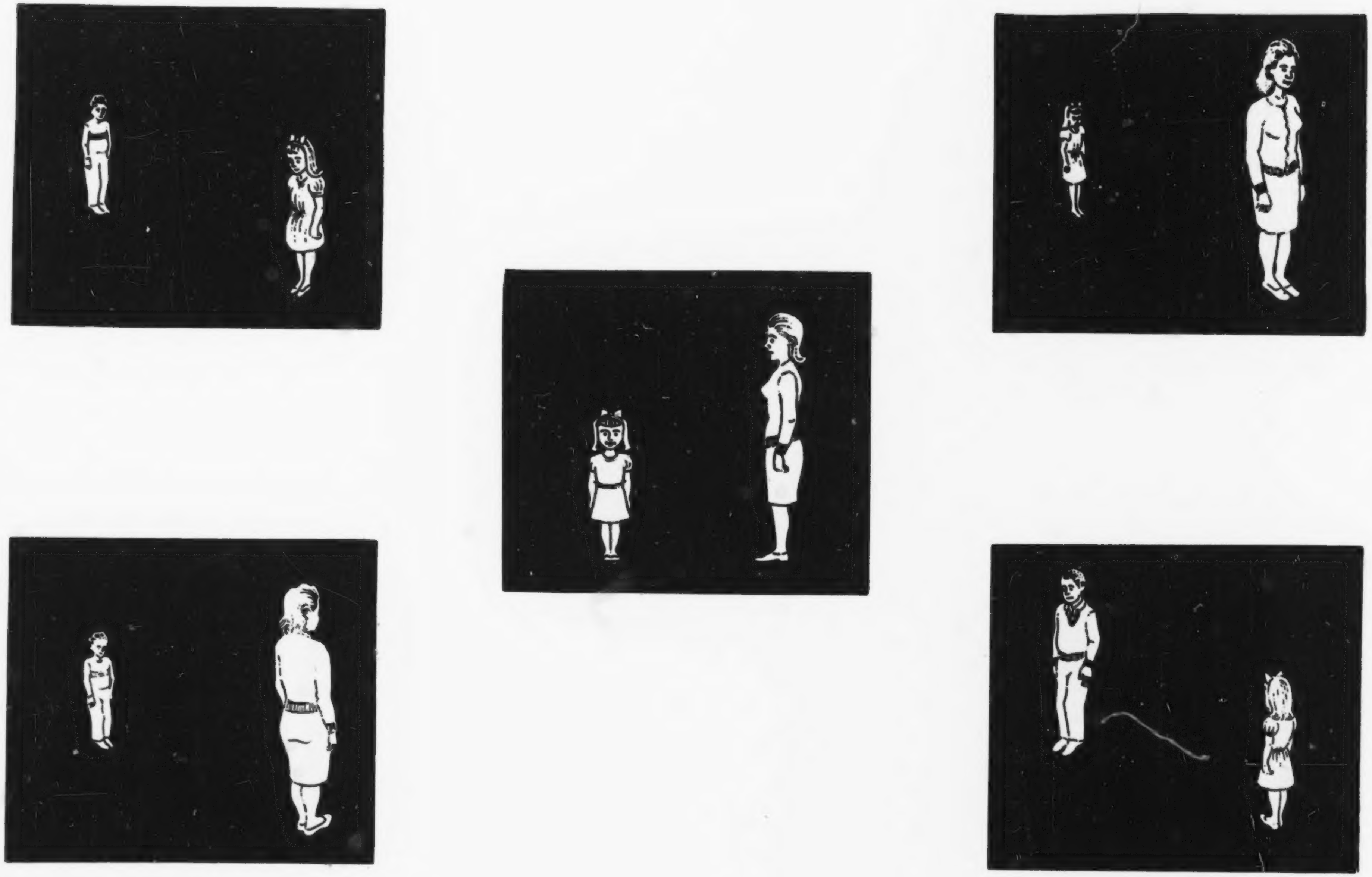

Fig. 4 An example of a 2D sample picture and 3D matching picture set

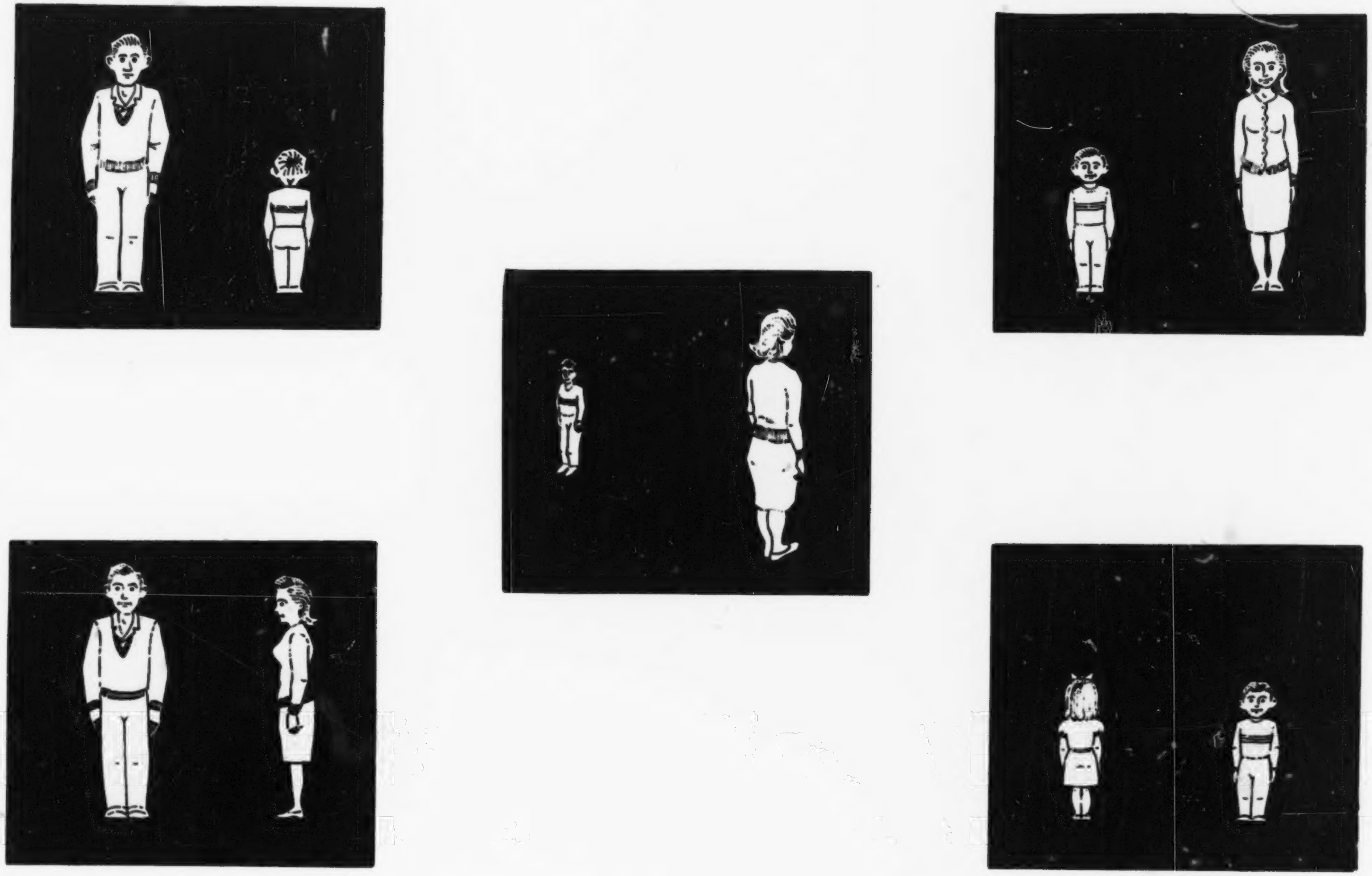

Fig. 5 An example of a 3D sample picture and 2D matching picture set

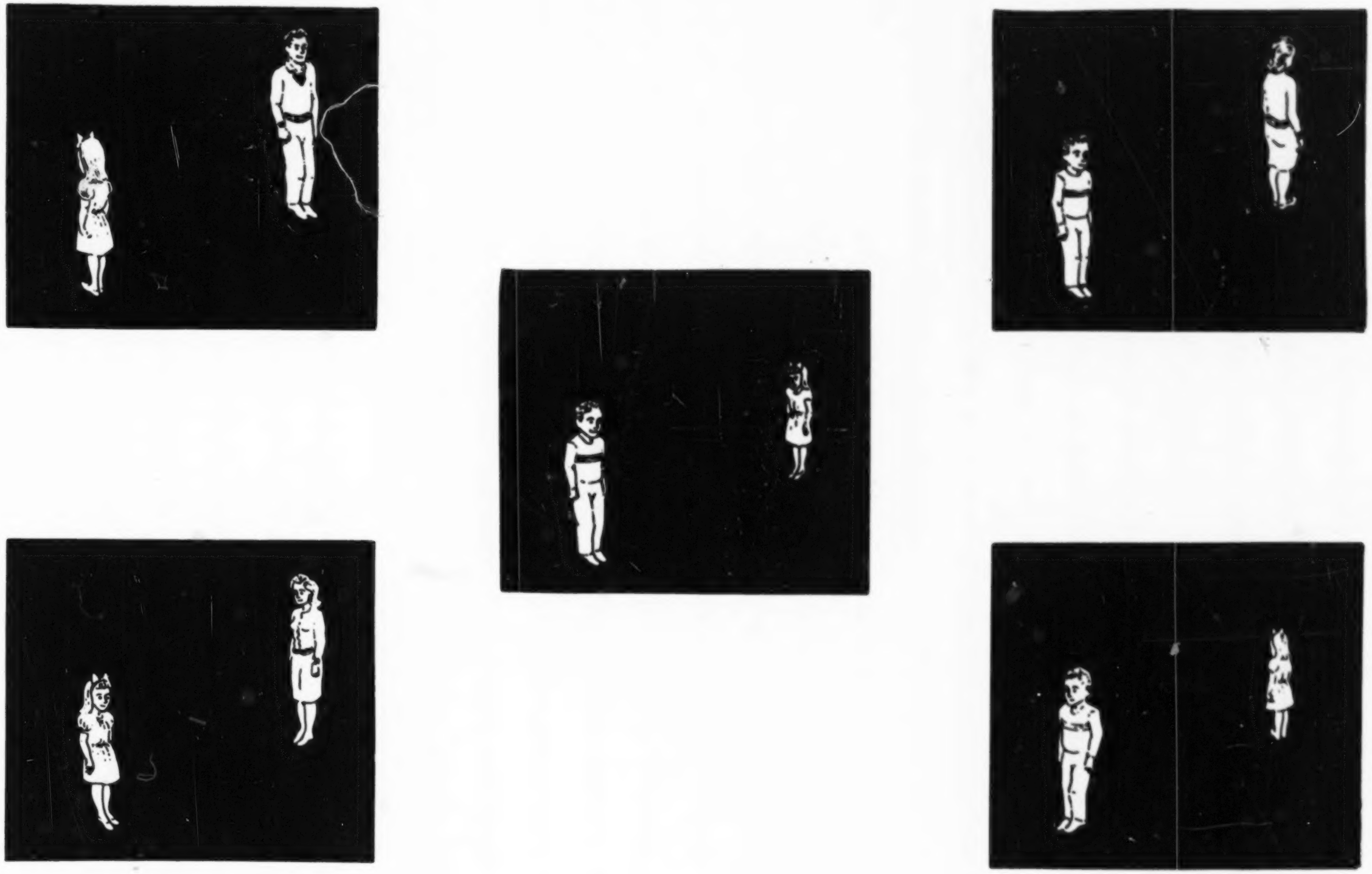

Fig. 6 An example of a 3D sample picture and 3D matching picture set

Half of the subjects were assigned to the Object Response group. They were informed that a response was correct when they chose a matching picture that included the same two figure-types as were included in the sample picture.

Half of the subjects were assigned to the Relation Response group. They were informed that a response was correct when they chose a matching picture that showed the left-hand figure and the right-hand figure facing in the same direction as the corresponding figures in the sample picture were facing.

Another factor of the experiment was called the Dimensionality of the picture. This factor had two levels. In some pictures, the two figures were represented as standing in the plane of the picture; that is, the figures did not appear to be separated by a dimension of depth. These pictures were called 2D pictures. In other pictures, one figure appeared to be separated from the other by a third spatial dimension. These pictures were called 3D pictures. The appearance of a third dimension was maintained in two ways. The separated figure was drawn shorter than it would have been if it had been standing beside the other figure. The height was determined by a pair of converging lines drawn to a vanishing point. All separated figures were drawn to appear as if they were the same distance from the figure in the forward position. The separated figures were also drawn higher in the picture frame than the other figures. These are two common techniques for representing a third dimension in a two-dimensional picture.

The "three-dimensional" picture differed from the "two-dimensional" pictures in yet another way. The figures in the "two-dimensional" pictures were rotated about a line perpendicular to an imaginary horizontal line. The figures in the "three-dimensional" pictures appeared as if the horizontal line through their bases had been rotated upward about 20°. Instead of facing directly into, out of, or across the picture plane, these figures faced obliquely about 20° from these positions. This control was necessary if the two three-dimensional figures were to maintain equivalent facing orientations with their corresponding two-dimensional pairs. Examination of sample stimulus materials presented in Figs. 3 through 6 will help to clarify the above description.

Dimensionality of picture constituted the basis of two factors of the experiment because both the sample picture and the matching picture were independently varied in dimensionality.

Given a sample picture, several limitations were placed on the construction of the matching pictures. These restrictions had two purposes. One was to design the pictures that were to be "incorrect" choices so that they would have some degree of similarity to the sample pictures and therefore not be automatically rejected as possible choices. Each figure-type shown in the sample picture was repeated in two or three matching pictures. More specifically, the object matching picture included both figure-types and each of the remaining matching pictures included one of the two figure-types shown in the sample picture.

Other restrictions on the design of the matching pictures were intended to reduce the possibility that subjects could consistently describe "correct" pictures in terms other than those used by the experimenter. The most likely way in which this could happen was for the subject to describe the figures as examples of a broader (superordinate) category than the one intended by the experimenter. Two possible alternative ways of describing the two figures is as some combination of sex types (e.g., two males) or as some combination of heights (e.g., a short and a tall figure). (Note that a combination of sex and height corresponds to the description used by the experimenter.) Given that the sample picture contained a particular height or sex combination, two matching pictures displayed this same combination so that a unique response could not be made on the basis of these descriptions. For example, if the sample picture showed a tall and a short figure, at least two of the matching pictures showed a tall and a short figure. Only one of these two would be a correct response. This procedure should have discouraged subjects from continuing to respond on the basis of a description which fitted more than one matching picture and which did not consistently result in the selection of a correct response. In a few cases it was impossible to accomplish both of the above limitations. In these cases only one matching picture agreed with the sample on the basis of identical sex combinations or height of figures combinations. In these cases the matching picture that fitted these descriptions was also the correct object response. Subjects who chose these responses on the basis of sex or height combinations were correct although they may have been using a description which would not be correct on later trials.

Initially, it was planned to have both the figures in the relation matching picture different than those in the sample picture.

It was then decided that the inclusion of one of the figure-types from the sample picture in each of the "incorrect" matching pictures would improve their function as attractive alternatives. If the relation picture was the only one of the matching pictures in which both figure-types were different from the figure-types in the sample picture, this difference would provide a second possible basis for forming a concept. To prevent this possibility, one figure-type from the sample picture was included in each relation matching picture.

The degree of control exercised with respect to the facing directions portrayed in the pictures was similar to that described above. The 16 different possible facing relations could be classified under one of three broader categories (among others). "Facing the same direction" (four pairs), "facing in opposite directions" (four pairs), and "facing 90° from each other" (eight pairs) are possible verbal labels for these configurations.

All sample pictures which could be described as "facing 90° from each other" included two such matching pictures so that the subject was required to choose the one matching picture that portrayed each figure facing in the same direction as the corresponding figure in the sample picture in order to be correct.

Through an oversight, some of the pictures which could be classified as "facing the same or opposite directions" did not have corresponding matching picture sets that included two alternatives of this description. For these picture sets, it was possible for subjects to respond correctly by using either of two descriptions of the pictures. This may have facilitated correct responding with these picture sets, but it may have interfered with correct choices of matching pictures where the two alternatives were presented.

The spatial position of the matching picture which was a correct choice for a given group was standardized for all groups. The upper-left hand corner and the lower-right hand corner positions were each correct three times and the remaining two positions were each correct two times. The serial order of spatial position of correct responses over picture sets was randomized but was made the same for all groups with the restriction that no spatial position would be correct twice in succession. This control was introduced to discourage hypotheses of spatial position as being related to correct responses.

With these limitations the production of pictures was made the responsibility of the artist. In retrospect, the design might have been improved if some of the arbitrary decisions had been made by a random procedure.

The two-level Response Type factor and the two-level factors of Dimensionality of sample and matching picture combinations constituted the eight treatment groups to which subjects were randomly assigned.

Apparatus. Subjects were seated in front of a rectangular panel, 27 inches wide and 21 inches high. The panel was placed on a table. The top of the panel sloped back at an angle of about 97 degrees. Five rectangular openings were located in the panel according to the arrangement shown in Fig. 7. Each opening was about 5 5/8 inches wide and 4 3/4 inches high. A plastic rear-projection screen was mounted behind each opening. The picture sets were projected on these screens. The screens were hinged and micro-switches were mounted behind each screen. Subjects indicated a choice of a matching picture by pressing on the screen where the picture appeared. The sample picture appeared on the center screen. The matching pictures were projected on the four screens surrounding the center screen. Near the outside edge of each of the matching picture screens was a small incandescent lamp. When the subject pressed on the screen which was the "correct" matching picture, the lamp adjacent to this screen was lighted.

The experimental procedure was automatically controlled by a solid-state logic system. A diagram of the system is presented in the Appendix. When a slide was projected on the panel the subject was required to press first on the center screen. The purpose of this requirement was to increase the probability that the subject looked at the sample picture. If this response did not preceed other pressing responses, such responses resulted in turning off the projector lamp for an interval of five seconds. The subject was reminded that he must press on the center screen. After pressing on the center screen the subject chose a matching picture by pressing on the screen where that picture was projected. These responses were recorded on an event recorder.

Identification of the position of the correct matching picture was punched in the cardboard slide mount. The light was projected through these holes and energized a combination of three photo cells.

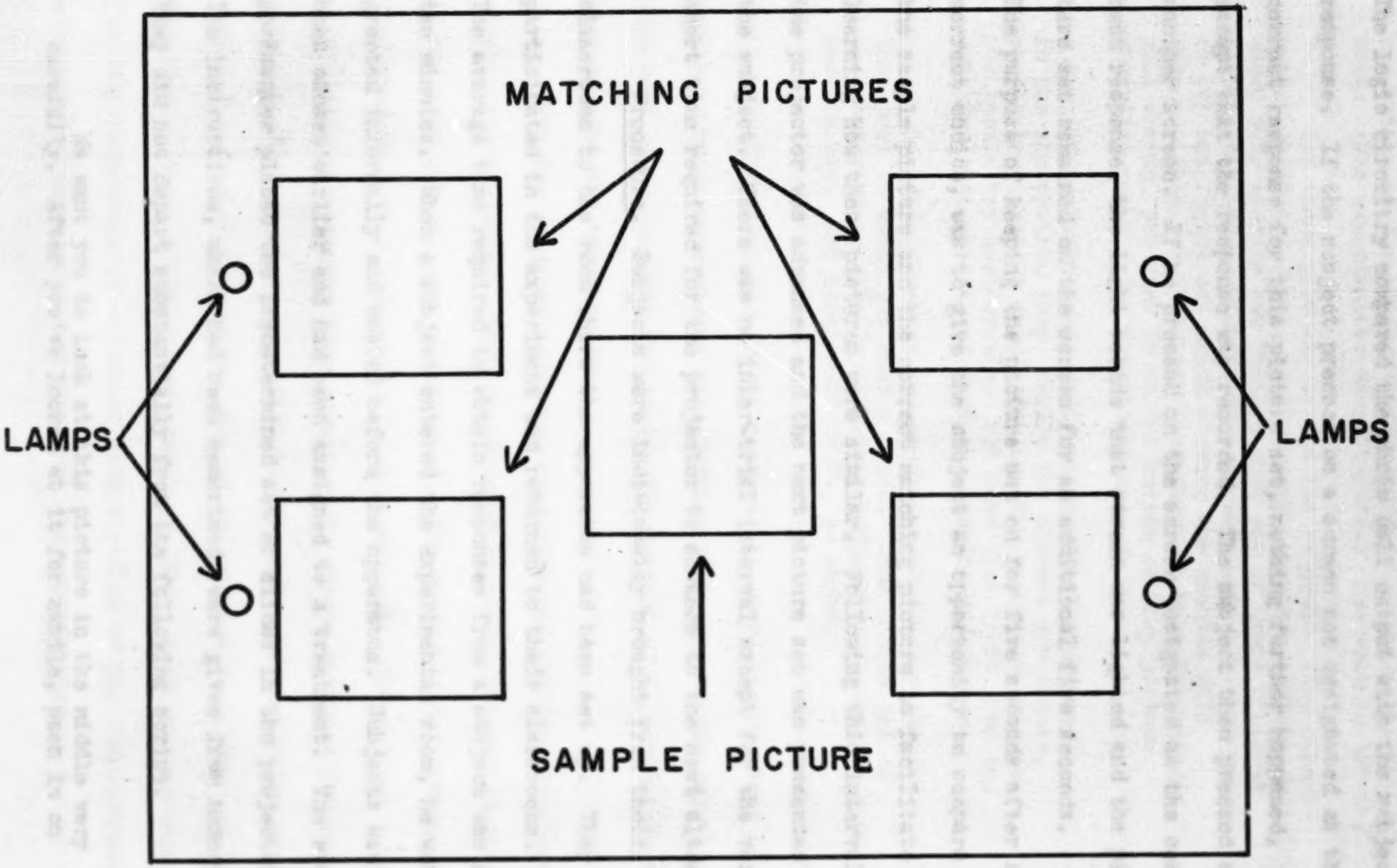
MATCHING PICTURES
LAMPS
LAMPS
SAMPLE PICTURE

Fig. 7. Spatial arrangement of the sample and matching pictures on the response panel

The logic circuitry compared the photo cell output with the subject's response. If the subject pressed on a screen not designated as the correct response for this picture set, nothing further happened, except that the response was recorded. The subject then pressed on another screen. If he pressed on the screen designated as the correct response, the light beside that screen was lighted and the picture set remained on the screen for an additional five seconds. The purpose of keeping the picture set on for five seconds after a correct choice, was to give the subject an opportunity to compare the sample picture and the correct matching picture to facilitate learning how these pictures were similar. Following this interval, the projector was advanced and the next picture set was presented to the subject. There was no inter-trial interval except for the very short time required for the projector to advance to the next slide.

Procedure. Subjects were individually brought from their classrooms to the room where the apparatus had been set up. They participated in the experiment and returned to their classrooms. The average time required to obtain responses from a subject was about ten minutes. When a subject entered the experimental room, he was greeted informally and seated before the apparatus. Subjects had been chosen earlier and had been assigned to a treatment. The experimenter placed the predetermined set of slides in the projector. The instructions, which had been memorized, were given from memory. They did not depart substantially from the following script.

> We want you to look at this picture in the middle very carefully. After you've looked at it for awhile, push in on

> the bottom of the picture until you hear a click--like this. (The experimenter demonstrated.) You want to try it?
>
> See these pictures around the outside? (The experimenter pointed.) Well, they're very important too, because this machine has decided that one of these pictures is like the middle picture in a certain way. We want you to try and figure out which picture the machine will choose. When you think you know which picture the machine will choose, you push in on the bottom of that picture just like you did for the middle one.
>
> If no light comes on (the experimenter pointed to the appropriate lamp) beside the picture you choose, you'll know that it wasn't the one the machine wanted so you should try another one. But when that light goes on, you know that was the picture the machine had chosen.
>
> Remember, look at the middle picture carefully, then push in until you hear a click. Then choose one of the four pictures that's like the middle picture in a certain way. Any questions? O.K., go ahead.

For the first and fourth graders the above instructions were preceeded by a two sentence introduction referring to the experiment as a detective game and asking the subject if he would like to play it with the experimenter.

Very few subjects indicated that they had any questions concerning the procedure. When questions were asked, relevant sections of the instructions were paraphrased. The subject's performance also indicated that they understood the instructions. Three first graders were eliminated because they continued to choose pictures during the interval after the lamp signified that a correct response had been made and before the projector changed the picture set. The performance of these subjects was puzzling. These performances were the only indication of a lack of understanding of the instructions, or an unwillingness to cooperate with the experimenter.

As the subject began responding, if he chose an incorrect picture on the first set of pictures, the experimenter said, "Keep trying until you find the one the machine wanted." If the subject chose a correct picture on the first set, the experimenter said, "Now look at these two pictures (the experimenter pointed to the middle picture and the picture which was correct) and try to see why the machine thought they were alike." No further comments were made after responses to the first set of pictures were completed.

Subjects were allowed to proceed at their own rate. The order of presentation of picture sets was fixed and was identical for all treatments. After completing ten trials each subject was asked if he knew how the pictures were alike. The verbal responses were recorded by the experimenter.

The collection of data took about three weeks. There was no basis for expecting a difference of a few days to have an effect on the responses. Therefore, precautions were not taken to systematically order the collection of data among schools and grades. The date for collecting data in a given school was primarily determined by convenience.

Results

An analysis of variance for repeated measures on one factor (five blocks of presentations of two picture sets each) was applied to the data. A Model I analysis (Winer, 1962) was judged most appropriate since none of the factors were the result of a sampling process but were considered as fixed factors.

A visual examination of the frequency distributions of the number of errors in the twenty-four cells (summed over all five blocks of trials) indicated that the distributions departed from normality. Many of the cells exhibited J-shaped exponential error score distributions with positive skewness. A frequency distribution plot of all scores exhibited this same shape. Experimental comparisons of F distributions resulting from comparisons of samples from non-normal distributions have shown that violation of the assumption of normality of distribution of the F test does not seriously affect the interpretation of the analysis. That is, the probability of making a Type I error is approximately the same when comparing samples from non-normal distributions as when comparing samples having a normal distribution (Anderson, 1961; Boneau, 1960; Lingquist, 1953).

A Hartley test for homogeneity of variance was computed. The ratio of largest to smallest sum of squares from among the twenty-four cells (equal number of observations for all treatments) was $F_{max} = 115$. The appropriate degrees of freedom for finding the critical value of F_{max} is $F_{.95}(24,9)$. The closest tabled value (Winer, 1962) is $F_{.95}(10,9) = 9.91$. Although most references on departure from the assumption of homogeneity of variance take the position that moderate departures do not seriously affect the interpretation of the analysis, it was felt that these variances represented a marked departure from homogeneity. Therefore, the error scores were transformed. Due to the nature of the distributions and the large number of zero scores, it was decided to transform the scores by using a $\log_{10} (x + 1)$

transformation where x was the number of errors made in a block of two picture presentations. A preliminary comparison of the variances of the same two extreme cells compared above indicated that the assumption of homogeneity of variance could be accepted for the transformed data, $F_{max} = 6.3$.[1]

The summary table of the analysis of variance of the transformed scores are presented in Table 7. Prior to conducting the experiment it was decided to use the .05 level of confidence as the standard for determining whether an F ratio would be judged as significant. Only those ratios exceeding the appropriate critical F values are reported in the table. The error term for the between-subject comparisons has 216 degrees of freedom. The critical F ratios are $F_{.95}(1,200) = 3.89$ and $F_{.95}(2,200) = 3.04$. For the within-subject comparisons, the error term has 864 degrees of freedom and the critical F ratios are $F_{.95}(4,\infty) = 2.37$ and $F_{.95}(8,\infty) = 1.94$.

Two hypotheses were advanced prior to conducting this experiment. Both of these hypotheses predicted interaction effects. The hypotheses will be restated in terms appropriate to the analysis of the experiment. The restatement reflects changes in the design of the experiment and the transformation of the measurement of the dependent variable. The first hypothesis stated that the difference in index of errors between the Object Response group (the group for which

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[1] These tests apply only to the between-subject comparisons. It is possible on repeated measures designs to test assumptions of homogeneity of variance and covariance. This test involves considerable computation and since most of the interesting differences found did not involve assumptions of homogeneity of covariance this test was not applied.

Table 7

Summary of Analysis of Variance

Between Subjects Comparison

Source of variation	Sum of squares	Degree of freedom	Mean square	F ratio
A (Grade in school)	5.7447	2	2.8724	17.29
B (Response type)	15.5017	1	15.5017	93.32
C (Dimensionality of sample picture	.0732	1	.0732	
D (Dimensionality of matching picture	.1245	1	.1245	
AB	1.3658	2	.6829	4.11
AC	.0604	2	.0302	
AD	.1556	2	.0778	
BC	.0008	1	.0008	
BD	.8502	1	.8502	5.11
CD	.5386	1	.5386	
ABC	1.3636	2	.6818	4.10
ABD	1.3699	2	.6850	4.12
ACD	.0516	2	.0258	
BCD	1.3443	1	1.3443	8.09
ABCD	.69637	2	.3482	
Subjects within groups	35.8837	216	.1661	
Between subjects	65.1249	239		

(Table continued on next page)

Table 7 (Continued)

Within Subjects Comparison

Source of variation	Sum of squares	Degree of freedom	Mean square	F ratio
E (Blocks of 2 trials)	7.3186	4	1.8296	54.10
AE	.7008	8	.0876	2.59
BE	.2390	4	.0597	
CE	.0593	4	.0148	
DE	.1291	4	.0323	
ABE	.1707	8	.0213	
ACE	.2713	8	.0339	
ADE	.2149	8	.0269	
BCE	.1211	4	.0303	
BDE	.1351	4	.0338	
CDE	.2669	4	.0667	
ABCE	.2558	8	.0319	
ABDE	.2207	8	.0276	
ACDE	.2008	8	.0251	
BCDE	.2276	4	.0569	
ABCDE	.5460	8	.0682	2.02
E x subjects within groups	29.2477	864	.0338	
Within subjects	40.3285	960		
Total	105.4533	1199		

a correct response was the picture containing the same two figure-types as the sample picture) and the Relation Response group (the group for which a correct response was the picture in which the two figures were facing in the same direction as the figures in the sample picture) will decrease as grade in school increases. The hypothesis predicted a two-way interaction between the grade in school factor and the Response Type factor (AB interaction). It also predicted the direction of the interaction. The hypothesis is supported by the data. Table 7 shows a significant difference for the AB interaction. Figure 8 shows that the direction of the interaction corresponds to the predicted direction.

The second hypothesis predicted that the error index would be higher for the subjects responding to sample and matching picture sets of different dimensions, than for subjects responding to picture sets of the same dimension; but the error index difference would be greater for subjects in the Relation Response group than for those in the Object Response group. The hypothesis is tested by combining the cells of the BCD summary table, which is presented in Table 8, according to the following formula.

$$\left[(63.27809 + 70.80306 - 49.47596 - 51.81175) - (27.37755 + 18.42728 - 20.02250 - 33.15232)\right]^2/150 \times 8 = 40.1634^2/1200 = 1.3443$$

The sum of squares resulting from this combination is 1.3443. For such a combination there is one degree of freedom so an F ratio of this quantity equals 8.09 which is a significant difference. The hypothesis is supported.

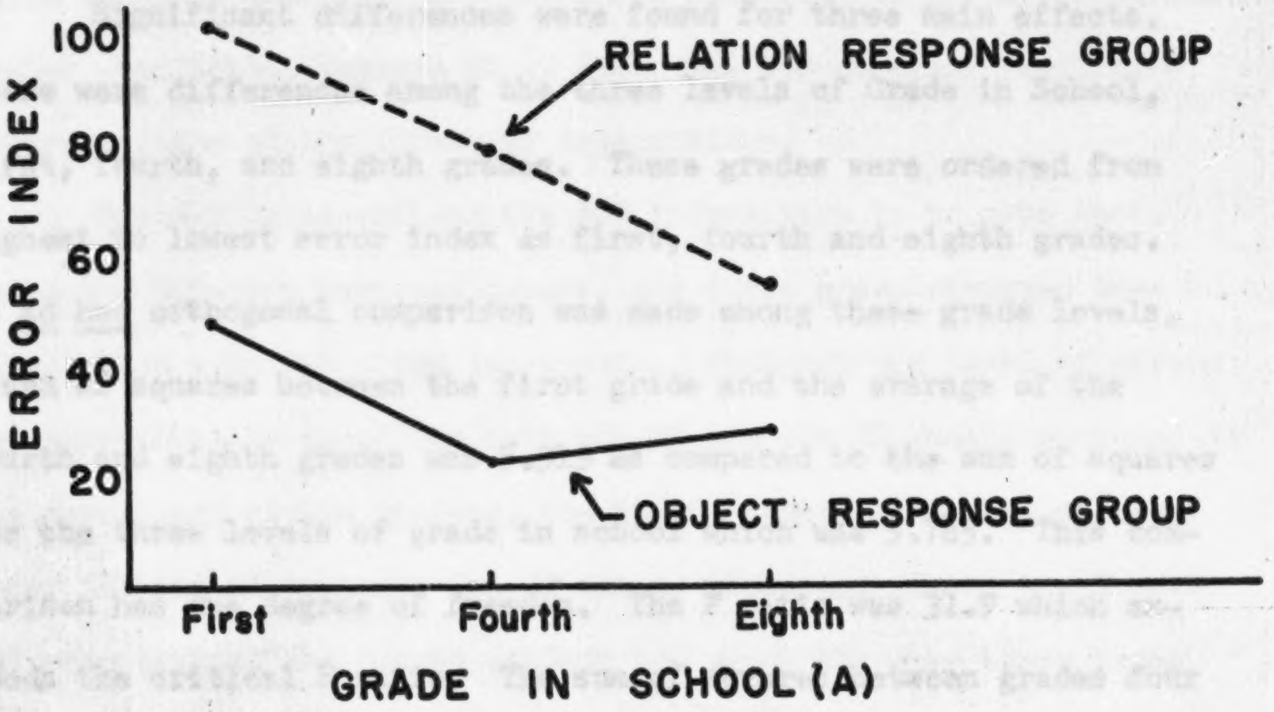

Fig. 8. Interaction of grade in school (A) by response type (B)

Table 8

Summary of BCD Sums of Squares

	2D sample 2D match	2D sample 3D match	3D sample 2D match	3D sample 3D match
Object response	20.02250	27.37755	18.42728	33.15232
Relation response	51.81175	63.27809	70.80306	49.47596

Significant differences were found for three main effects. There were differences among the three levels of Grade in School, first, fourth, and eighth grades. These grades were ordered from highest to lowest error index as first, fourth and eighth grades. An ad hoc orthogonal comparison was made among these grade levels. A sum of squares between the first grade and the average of the fourth and eighth grades was 5.313 as compared to the sum of squares for the three levels of grade in school which was 5.745. This comparison has one degree of freedom. The F ratio was 31.9 which exceeds the critical F ratio. The sum of squares between grades four and eight amounted to 0.432. The difference between fourth and eighth grades was not significant. The Grade in School factor was also involved in several interaction terms which will be presented later.

A significant difference was found between the Object Response groups and the Relation Response groups. The Relation Response group had a higher error index than the Object Response group. This Response Type factor also entered into several interactions which demonstrated significant differences.

The third significant difference attributed to a main effect was among levels of blocks of two picture set presentations. The error index decreased over trials demonstrating a learning effect.

Significant three-way interactions were found for combinations of Grade in School (A), Response Type (B), and Dimensionality of both sample picture (C) and matching picture (D). The ABC interaction is presented in Fig. 9 and the ABD interaction in Fig. 10. The data on which these interactions are based are presented in graphic diagrams rather than tables because it is felt that the diagrams facilitate interpretation of the three-way interactions.

One way of describing the ABC interaction is to note that, among the Relation Response groups, the first grade diverged from parallelism with the other two groups. Although the index of errors was approximately equal for both the 2D and the 3D sample pictures for the fourth and eighth graders, the first graders had a higher error index for the 3D than for the 2D sample pictures. Among the Object Response groups, the fourth graders had about the same error index for both the 2D and the 3D sample pictures but the first and eighth graders although having the same error index for the 3D sample pictures diverged for the 2D sample pictures. The first graders had a higher index of errors and the eighth graders a lower index of errors for the 2D as compared to the 3D sample pictures.

A similar analysis can be made for the ABD interaction. Among the Object Response groups the fourth and the eighth graders had a higher error index for the 3D matching pictures than for the 2D

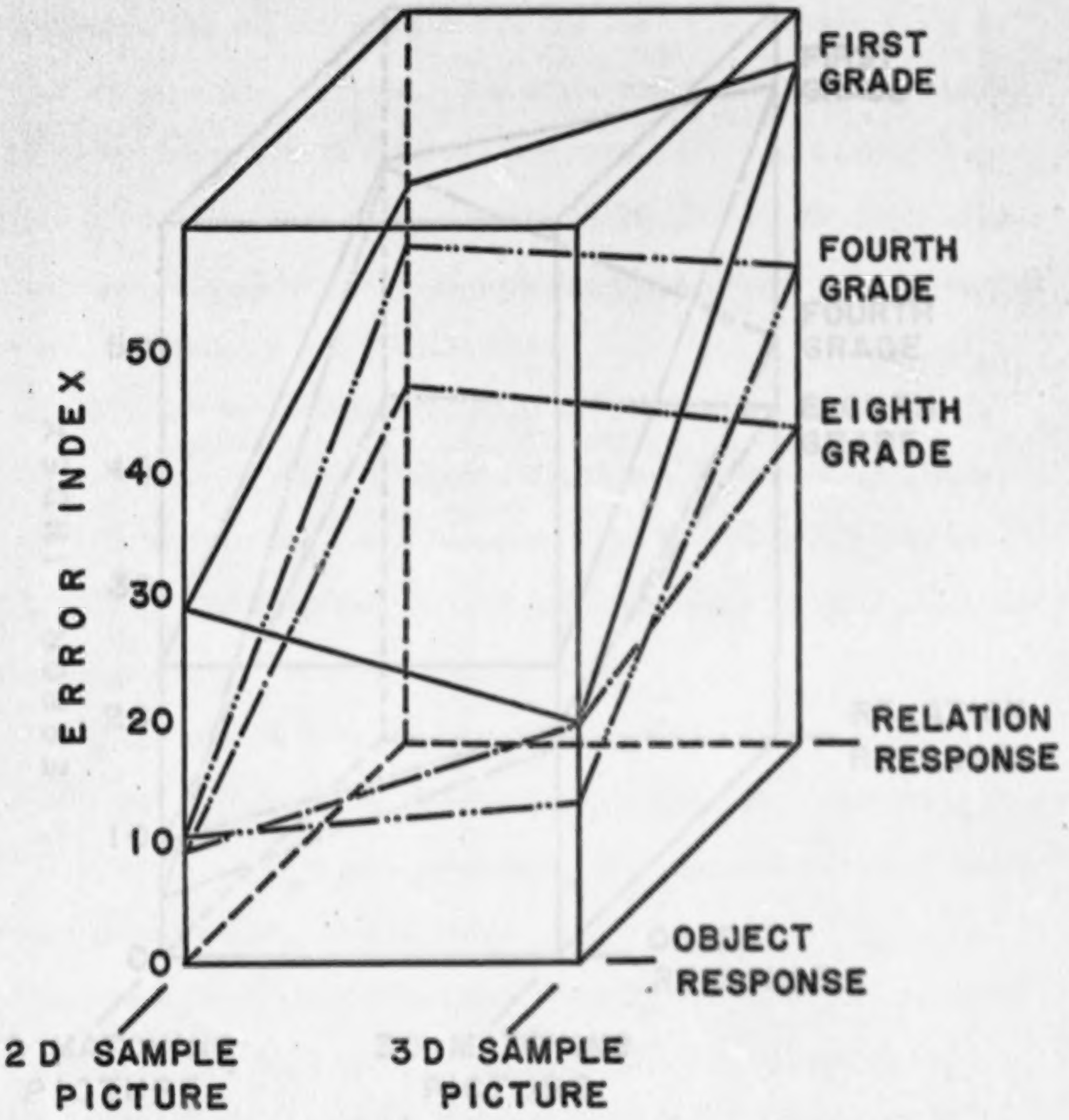

Fig. 9. Three-way interaction among grade in school (A), response type (B), and dimensionality of sample picture (C).

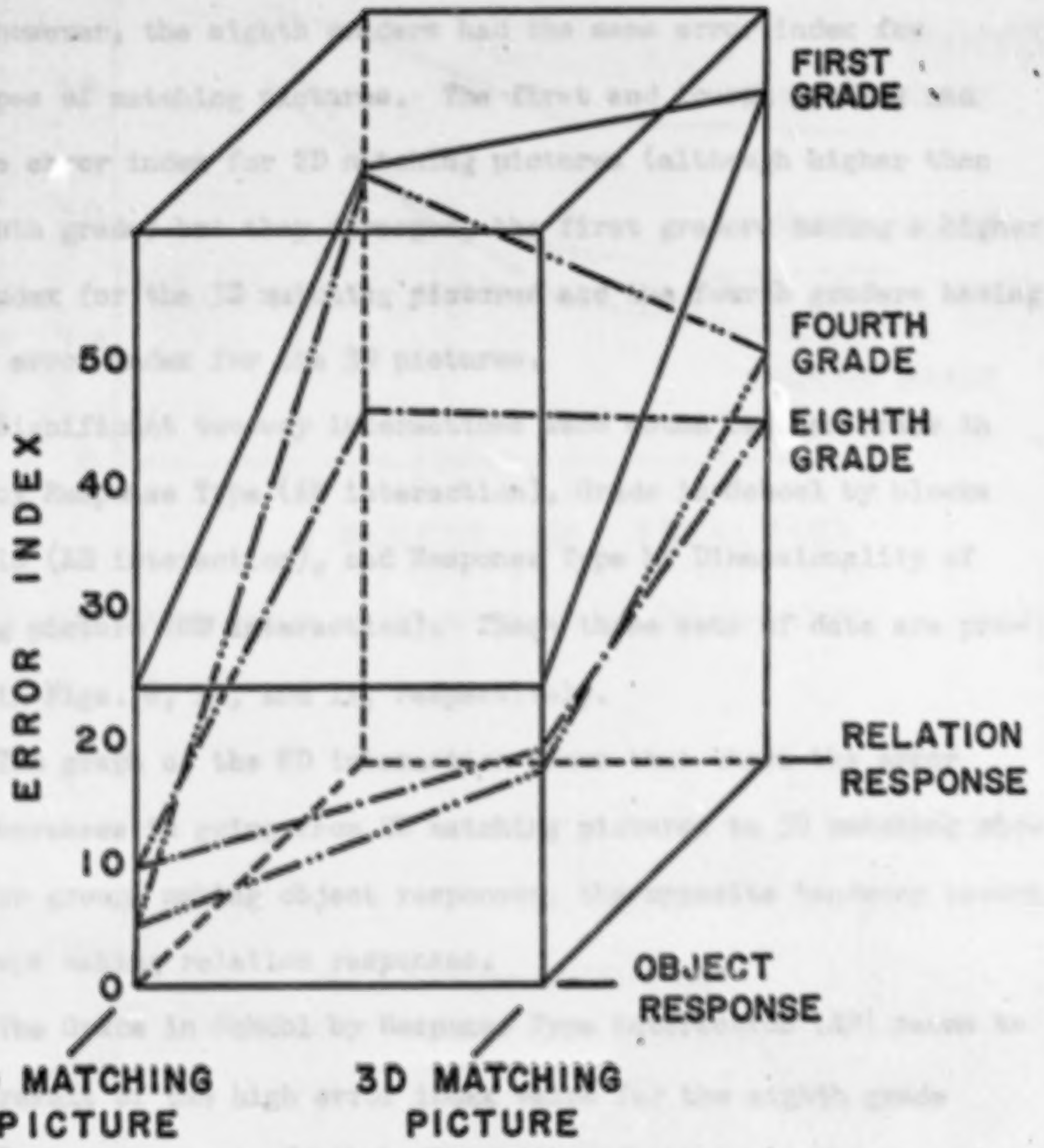

Fig. 10. Three-way interaction among grade in school (A), response type (B), and dimensionality of matching picture (D).

matching pictures while the first graders had the same error index for both types of matching pictures. Among the Relation Response groups however, the eighth graders had the same error index for both types of matching pictures. The first and fourth graders had the same error index for 2D matching pictures (although higher than the eighth grade) but they diverged, the first graders having a higher error index for the 3D matching pictures and the fourth graders having a lower error index for the 3D pictures.

Significant two-way interactions were found between Grade in School by Response Type (AB interaction), Grade in School by blocks of trials (AE interaction), and Response Type by Dimensionality of matching picture (BD interaction). These three sets of data are presented in Figs. 8, 11, and 12, respectively.

The graph of the BD interaction shows that where the error index increases in going from 2D matching pictures to 3D matching pictures for groups making object responses, the opposite tendency occurs for groups making relation responses.

The Grade in School by Response Type interaction (AB) seems to be the result of the high error index value for the eighth grade Object Response group. Further discussion of the implications of this interaction term will be presented in the following section.

The Grade in School by blocks of trials interaction (AE) seems to be the result of different rates of learning in the early trials of the experiment. There is also some difference in that the eighth grade error index is still decreasing on the fifth block of trials while the scores of the other two groups seem to indicate that they

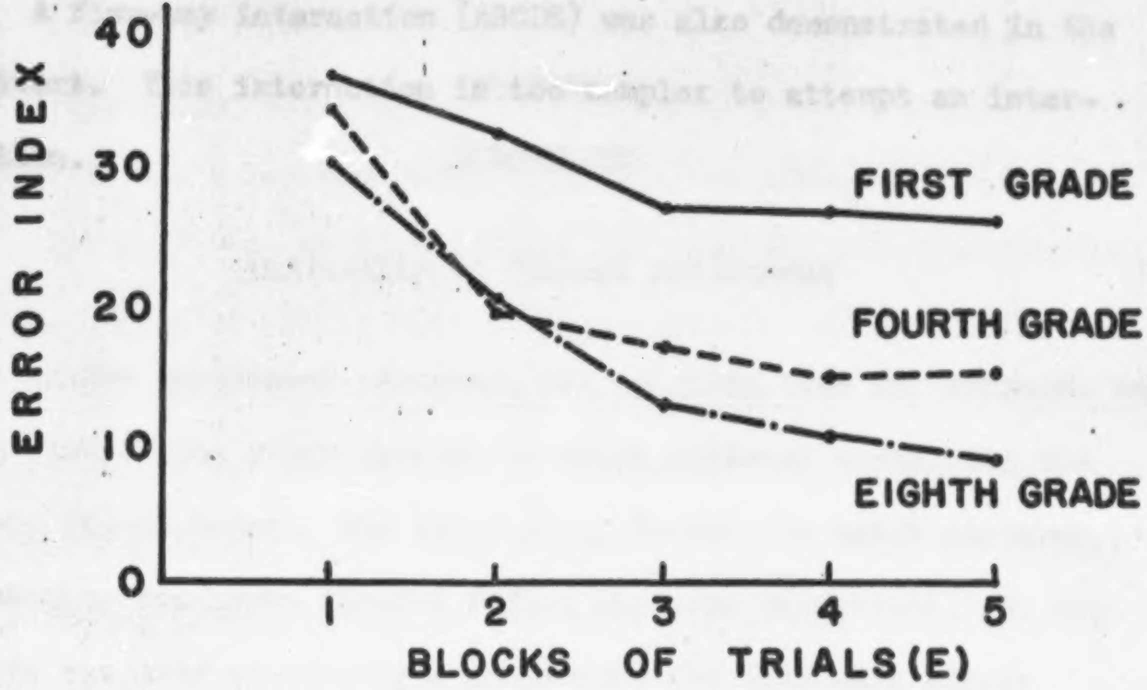

Fig. 11. Interaction of grade in school (A) and blocks of trials trials (E)

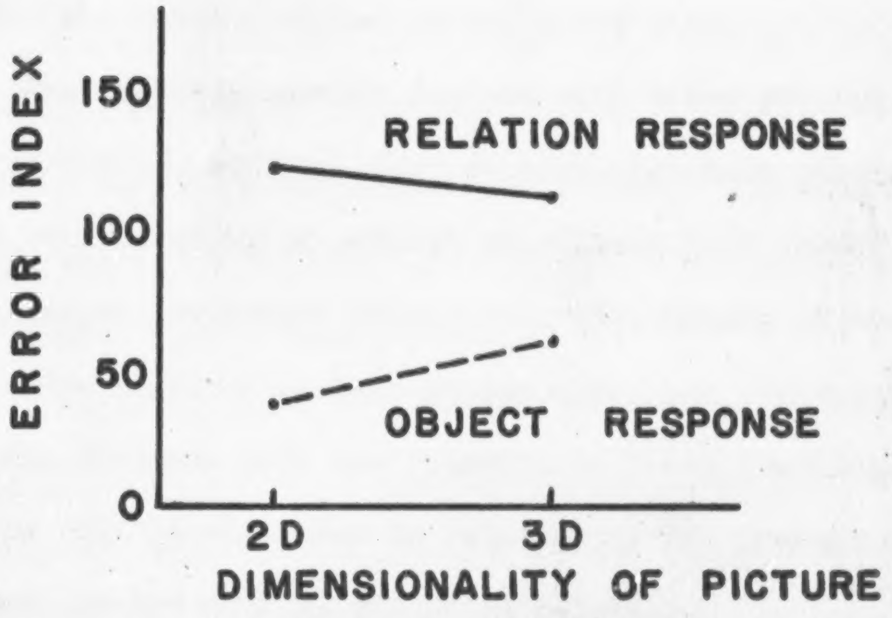

Fig. 12. Interaction of type of response (B) and dimensionality of matching picture (D)

have reached an asymptote.

A five-way interaction (ABCDE) was also demonstrated in the experiment. This interaction is too complex to attempt an interpretation.

CHAPTER V

DISCUSSION

Difficulty of Concept Attainment

In the experiment reported, the matching task for subjects was of two kinds. One group learned to match pictures containing the same two figure-types. The other group learned to match pictures representing two human figures facing the same directions. No hypothesis was made concerning a difference for this main effect (Response Type). The expectation was that this factor would interact with age, but not necessarily that a difference in the main effect would be found. The results of a pilot study, not reported, suggests that there may be a difference between the performances of adult subjects who match pictures in these two ways.

How do these results compare with other studies reported in the literature? At least four factors that have demonstrated an effect on difficulty of concept attainment were reported. These were the number of irrelevant dimensions, obviousness of the dimension, qualitative differences between concepts, and individual differences among the subjects that are relevant to these learning tasks. Each of these will be discussed in relation to the present study. The last two factors will be discussed together.

The number of irrelevant dimensions. Bourne and Restle (1959) summarized several studies which showed that concept attainment is more difficult when the number of irrelevant dimensions are increased and the number of relevant dimensions are held constant. The dimensions and values that may be used to describe the stimulus materials presented in the experiment being discussed were height of figure (short and tall), sex of figure (male and female), and direction in which the figure is facing (one of four values). Using this description of the stimulus materials, relevant dimensions for matching figure-types are the height and sex of the left hand figure, and the height and sex of the right hand figure. The irrelevant dimensions are the facing direction of the left hand figure and the facing direction of the right hand figure.

For the relation matching task the relevant dimensions are the facing direction of the left hand figure and the facing direction of the right hand figure. The irrelevant dimensions are the height and sex of both figures.

In this experiment, both matching tasks had the same number of irrelevant dimensions. One complicating factor was that the different dimensions had different numbers of values. The experiments demonstrating the reported effect of the number of irrelevant dimensions used only two-valued dimensions.

Another complicating factor in this experiment was that the experimenter did not know how the subjects described the stimuli. No effort was made to communicate to the subjects the dimensions and values which were to be used in analyzing the stimulus materials. It is possible that the subjects combined the sex and height dimensions into one dimension, human figure. This dimension has four values;

boy, girl, man, and woman. If subjects described the stimuli in this way, the object response, had more irrelevant dimensions, than the relation response. However, subjects matching the same figure-types had the lower error index. It is speculated that the reported effect of the number of irrelevant dimensions is demonstrated only with materials where obviousness, or ease of discrimination, of dimensions is fairly equal.

The possibility suggested in the preceeding paragraph, that subjects may describe materials differently, introduces another possible difference among subjects. When two particular values of two different dimensions always occur together, and when both are a part of the description of the concept, they are referred to as redundant relevant dimensions. Bourne and Haygood (1959) have reported that increases in the number of redundant relevant dimensions improve concept attainment. In the context of the laboratory situation, it is possible to apply this terminology to the stimulus materials. It is assumed that the sex dimension is a combination of differences in hair, body shape, facial features, etc. Certain differences in clothing covary with the two values of sex, so that these may be considered as redundant relevant dimensions. Other dimensions covary with the two values of height. For the male figure, type of sweater or shirt is redundant relevant, and for the female figure, presence or absence of a hair ribbon covaries with height. These dimensions were made to covary in the experimental materials because they are highly correlated in the same way in the real world. Recognition of this fact is implied by the suggestion that these dimensions can be combined into one at a different level; i.e., boy, man, girl, woman. The number of irrelevant dimensions and the number of redundant relevant dimensions depends on the way subjects describe the pictures.

It is to be regretted that verbal responses were not successfully obtained as these might have revealed how the subjects structured these materials.

The above description applies to all groups that reacted to the 2D-2D picture sets. An additional height difference was introduced in the 3D pictures. The forward figures in these pictures had the same heights as the 2D figures but the background figures were all reduced in height. This difference could have introduced differences in the ease of discrimination and the possibility of confusion.

The stimulus materials used in this study and the descriptions used by the subjects were too uncontrolled in terms of the number of irrelevant dimensions and the number of relevant redundant dimensions to relate the results of this study to the effect attributed to these stimulus variables in experiments where they were carefully controlled. Control of these aspects of the stimulus materials is difficult with this type of material. However, by exercising greater control over the production of stimulus materials and by instructing the subjects what dimensions are to be used in describing the stimulus materials, as recommended by Hovland (1952), greater precision can be attained in working with this type of stimulus material.

Obviousness of dimension. The difference in concept attainment found in this study cannot be attributed to the kind of differences between stimulus materials which Archer (1962) introduced.

Archer manipulated the degree of difference between two values of a dimension, and the obviousness of the dimension was effected. In the study being reported no such differences were introduced. It may seem natural to discuss the qualitative differences between dimensions in this experiment as differences in obviousness. If so, more precise terminology needs to be developed as the kinds of differences being discussed here are very different operationally than those Archer introduced.

Qualitative differences between concepts. The Shepard et al (1961) study demonstrated that concepts defined by different partitions of a set of eight stimuli resulted in different degrees of difficulty of concept attainment. It has also been demonstrated by Bruner et al (1956) that disjunctive concepts are more difficult to attain than conjunctive concepts.[1] In one experiment a thematic concept proved to be more difficult to attain than an abstract concept of similar dimensional structure (Bruner et al, 1956).

The present study seems to demonstrate a difference in denotation attainment between "thing" concepts and "relation" concepts. (Of course this generalization awaits verification with other samples from the population of things and relations.) There are probably many different factors confounded among these reported differences. Some possible factors (in addition to those already discussed) are differences in difficulty of discrimination, differences in patterns of learning and usage of different forms of concepts in the subjects' experiences prior to experimentation, the influence of language habits and patterns, set or predilection to entertain hypotheses of a limited kind, and probably many more. The experiment of Ryan and Schwartz (1963) and of Glanzer and Clark (1962) suggest techniques for measuring some of these factors.

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[1] A conjunctive concept is a classification rule specifying that a conjunction of values of two or more dimensions are necessary for an object to be a member of the denotation. A disjunctive concept is a classification rule specifying that either one dimension or another is sufficient for an object to be a member of a denotation.

Response predilection was demonstrated to be involved in the present study. On the first response, subjects chose the picture which was the correct object response more often than would be predicted by chance. Sixty-six per cent of the subjects chose the picture which was the correct object response as their first choice. Table 9 presents the first choices made by all subjects. There was no way to identify the alternative pictures across different sets of pictures so the total responses not made to either the object matching picture or the relation matching picture were evenly divided between the two alternative pictures.

Table 9

Distribution of First Choices of All Subjects
Among Four Matching Pictures

	Object Picture	Relation Picture	Alternates	
Observed	144	43	26.5	26.5
Expected	60	60	60	60

The Chi-square Test of the difference between the observed and expected number of choices of pictures was 140.82. The value of the Chi-square distribution for three degrees of freedom at the .05 level of confidence is 7.8. The difference is significant.

It would seem likely that the subjects predilection for the object picture would interfere with learning to choose the relation picture for those subjects in the relation group. If such were the case, a BE interaction (type of response x trials) or an ABE interaction should have been found. Neither of these interactions were significant.

Age differences in concept attainment. The difference among levels of grade in school was significant but, as reported earlier, the difference was primarily between the first graders and the average of the fourth and the eighth graders. Since level of grade in school rather than chronological age was controlled, the results will be reported in these terms.

Additional effects of age are evident in the interactions of age and other factors manipulated in the experiment. Fig. 8 presents graphically, the data from which an interaction of Grade in School by Response Type was computed. One way of describing the interaction is to note that the error index did not continue to decrease between the fourth grade and the eighth grade for the subjects in the Object Response group. Inspection of Fig. 13 reveals that the eighth graders in the Object Response group had less tendency than fourth graders to choose the object response on the first two blocks of trials. By the third block of trials both these groups were performing and continued to perform at the same error level. One explanation for this difference in the very early trials might be that the older children had

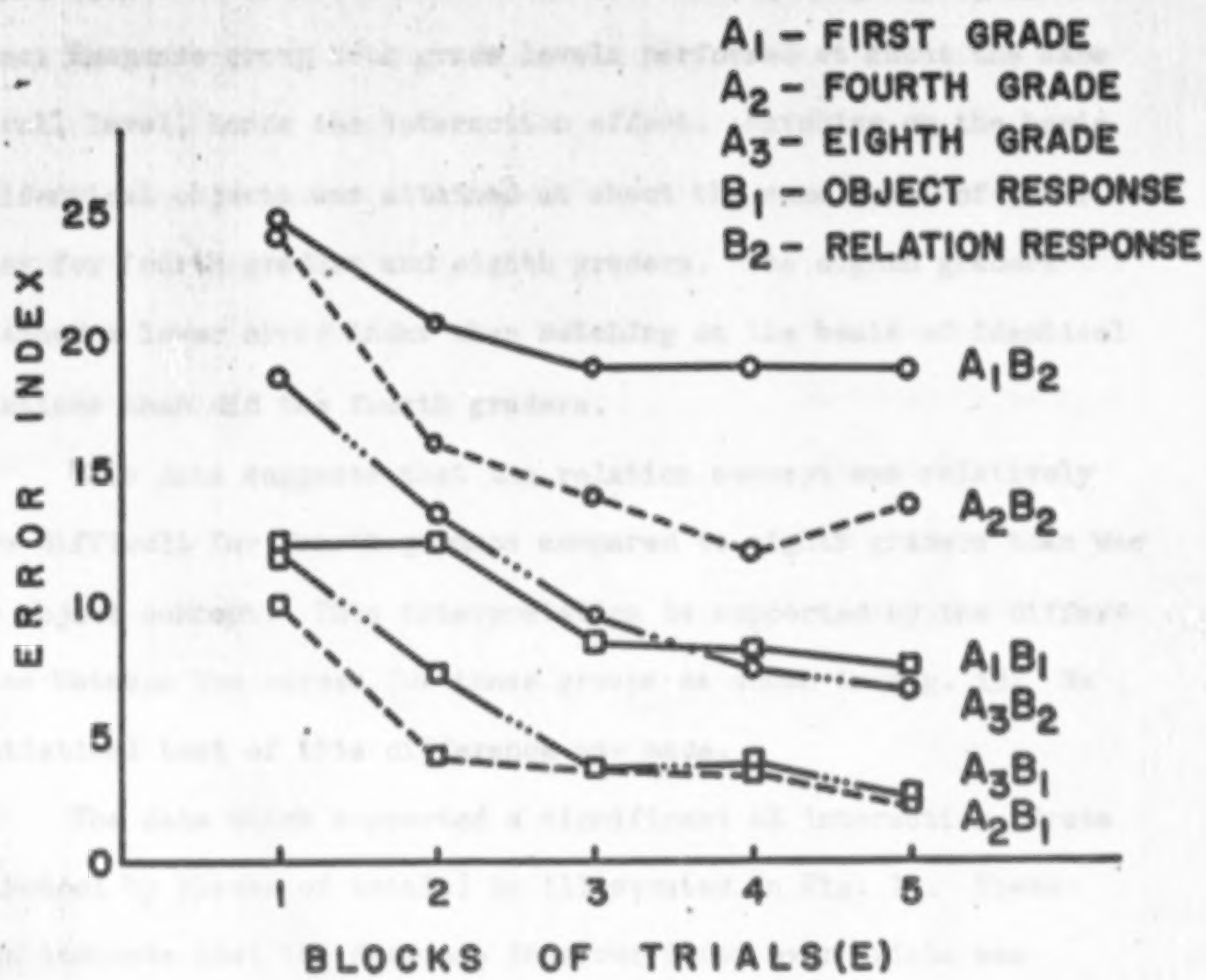

Fig 13. Three-way interaction among grade in school (A), response type (B), and blocks of trials (E)

more hypotheses at their disposal and therefore showed less predilection for the object response. The difference is so small that it should not be pursued further.

Although in the Relation Response group the eighth graders performed with a lower error index than did the fourth graders, in the Object Response group both grade levels performed at about the same overall level, hence the interaction effect. Matching on the basis of identical objects was attained at about the same level of error index for fourth graders and eighth graders. The eighth graders attained a lower error index when matching on the basis of identical relations than did the fourth graders.

This data suggests that the relation concept was relatively more difficult for fourth graders compared to eighth graders than was the object concept. This interpretation is supported by the differences between the curves for these groups as shown in Fig. 13. No statistical test of this difference was made.

The data which supported a significant AE interaction (Grade in School by blocks of trials) is illustrated in Fig. 11. These data indicate that the decrease in error index over trials was greater for the fourth and eighth graders than for the first graders.

Again it is difficult to relate these results to the experiments reported from the developmental investigation of concept learning. The general trend of better performance with increasing age is confirmed but this is hardly worthy of notice.

The main difficulty in relating this study to other concept learning studies is the lack of any method for comparing or relating different concepts. It should be possible to order concepts in terms of the logical structure of the concept in the context of a descriptive space. For example, Bruner (1963) reports that a much higher percentage of seven year olds (50%) demonstrated conservation of volume than were able to do so with a concept of fullness (16%). These results were obtained from displays of different sized beakers of water so that the content or the material manipulated was very similar. The definition of equal volume is $h_1a_1=h_2a_2$, where h is the height of the water and a is the area of the base of the beaker. To demonstrate conservation, the child has to be able to make appropriate changes in one of the dimensions when the other is manipulated by the experimenter. Area is a function of the square of a linear dimension making the compensation more complicated.

Equal fullness involves conceptualizing equal ratios of volume of water divided by volume of the container for the containers being compared. Concepts of equal fullness involve a more complex logical structure than does the concept of equal volume.

Concept learning experiments also should be related to the kinds of conceptualizing experiences children have had in extralaboratory situations. For example, Gibson (1963) has found that children's ability to discriminate classes of transformations on alphabet-like characters parallels discrimination training in real life situations. The ability to discriminate line-to-curve transformations improves rapidly at the age when a child is learning to read. This ability is requisite for letter discrimination with the English alphabet.

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Bruner (1964) argues persuasively for the importance of a better understanding of the role of language in concept learning with children. It may be possible to relate the ability for attaining some kinds of concepts to the development of related language skills. An attempt was made in this experiment, to ask subjects to explain how they matched pictures after completing the matching task. Two kinds of responses predominated. Many subjects who demonstrated ability to match pictures correctly, when asked to explain their behavior responsed, "I don't know." Other subjects made responses that were so vague and ambiguous that it became apparent that a carefully standardized funneling procedure would have to be used to elicit reliable responses of any value. (By the time this conclusion was reached, considerable data had been collected. Consequently, responses were deemphasized and are not reported.)

No analysis was done of individual performance patterns but inspection of individual performance records gives the impression that the decrease in error indices, over trials, was due to an increase in the proportion of the subjects beginning to make performances without errors. Some subjects never attained performances without errors and a few never made an error. An intriguing question is raised by these performance differences. How much of this difference can be attributed to chance variations? What factors other than chronological age or IQ may be related to these individual differences? Answers to these questions seem to be dependent on both additional relevant empirical data and on new ways of conceptualizing about behavior of this kind.

Picture dimensionality. Dimensionality of the picture entered into three 3-way interactions. Fig. 14 shows the data for the BCD interaction (Response Type by Dimensionality of sample picture by Dimensionality of matching picture).

As was predicted, subjects in the relation group had a lower error index for matches between picture sets of the same dimensions (2D-2D and 3D-3D) and a higher error index with picture sets of different dimensions (2D-3D and 3D-2D). The basis of this prediction was that the 20° difference in rotation of figures between the 2D and 3D pictures would increase the difficulty of making correct responses when the correct response was one of matching the directions in which the figures are facing.

It was not expected that differences in the dimensionality of picture would have a similar affect on the error index of the object response group. Therefore, a three-way interaction effect for BCD was predicted and was verified.

Interactions of ABC and ABD were also significant. Graphic presentations of these date are given in Fig. 9 and Fig. 10. The interactions are explained in general terms by reversals in the relative difficulty of 2D and 3D levels of dimensionality from object to relation matching tasks at some grade levels and not at others. The experimenter can offer no explanation for these results without engaging in what seems to be an appropriate dependence on speculation.

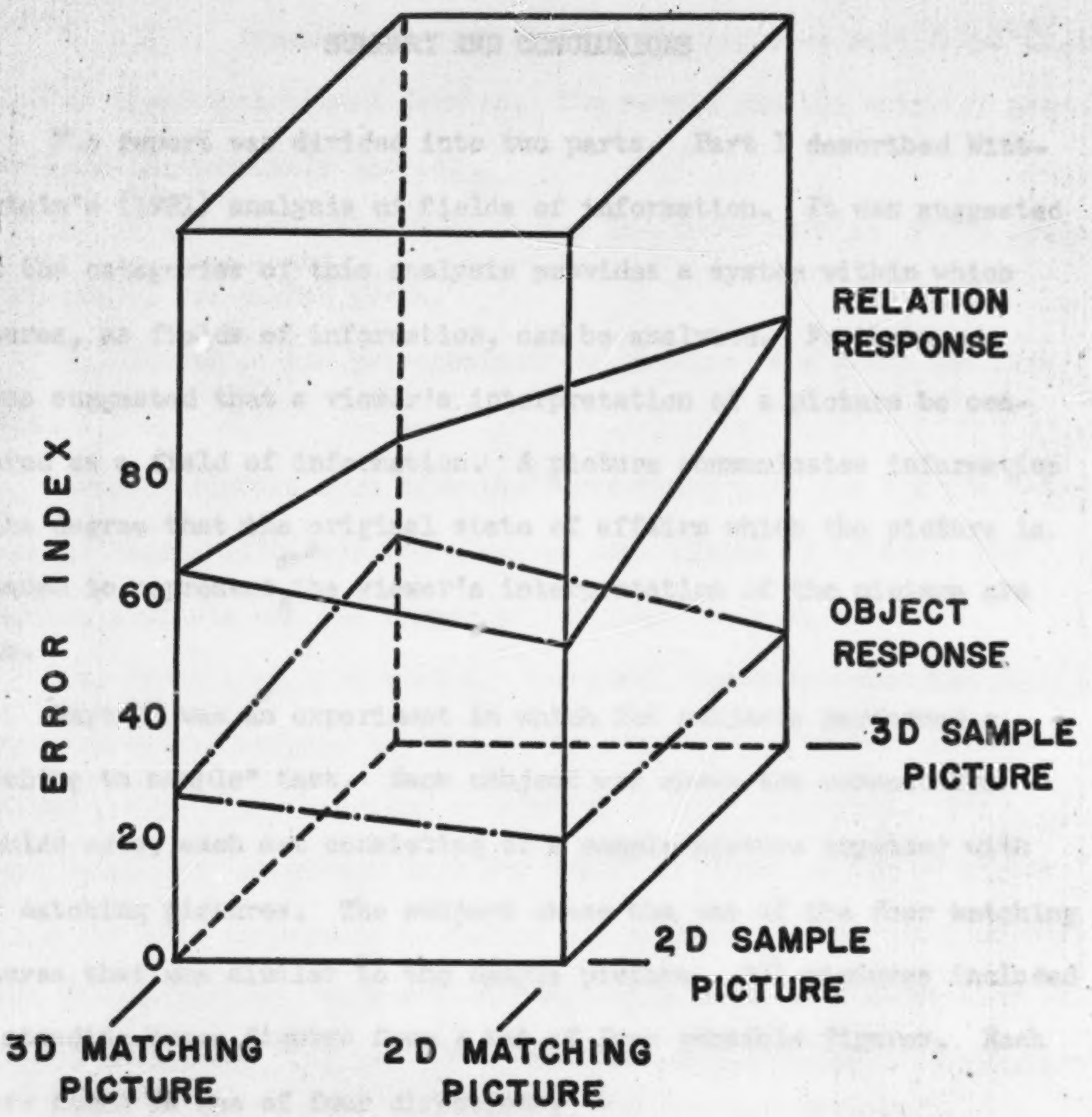


Fig. 14. Three-way interaction among response type (B), dimensionality of sample picture (C), and dimensionality of matching picture (D)

CHAPTER VI

SUMMARY AND CONCLUSIONS

The report was divided into two parts. Part I described Wittgenstein's (1921) analysis of fields of information. It was suggested that the categories of this analysis provides a system within which pictures, as fields of information, can be analyzed. Furthermore, it was suggested that a viewer's interpretation of a picture be considered as a field of information. A picture communicates information to the degree that the original state of affairs which the picture is intended to represent and the viewer's interpretation of the picture are alike.

Part II was an experiment in which 240 subjects performed a "matching to sample" task. Each subject was shown ten consecutive stimulus sets, each set consisting of a sample picture together with four matching pictures. The subject chose the one of the four matching pictures that was similar to the sample picture. All pictures included two standing human figures from a set of four possible figures. Each figure faced in one of four directions.

The independent variables were:

1. Response Type - the nature of the pictorial similarity on the basis of which subject was informed whether a choice was correct. For the Object Response group, the correct picture choice was the one in which the two human figures were the same as those in the sample

picture. For the Relation Response group, the correct picture choice was the one in which the two human figures were facing in the same directions as the figures in the sample picture.

2. and 3. Dimensionality - whether the pictures were drawn in a two- or three-dimensional fashion. The sample and the matching pictures were independently varied.

4. Grade in School. This factor had three levels: first grade, fourth grade, and eighth grade.

5. Blocks of two presentations of picture sets which had five levels.

These variables were combined factorially in a 3 x 2 x 2 x 2 x 5 factorial design with repeated measures over blocks of trials. The dependent variable was the number of incorrect choices.

Two hypotheses were tested. The first predicted that the difference in errors between the Object Response group and the Relation Response group, would decrease as grade in school increased. The second hypothesis predicted that the number of errors would be higher for the subjects responding to sample and matching picture sets of different dimensionality, than for subjects responding to picture sets of the same dimensionality; but the difference in errors would be greater for subjects in the Relation Response group than for those in the Object Response group. Both hypotheses were confirmed. In addition, three main effects (Grade in School, Response Type, and blocks of trials) and several interactions demonstrated significant differences.

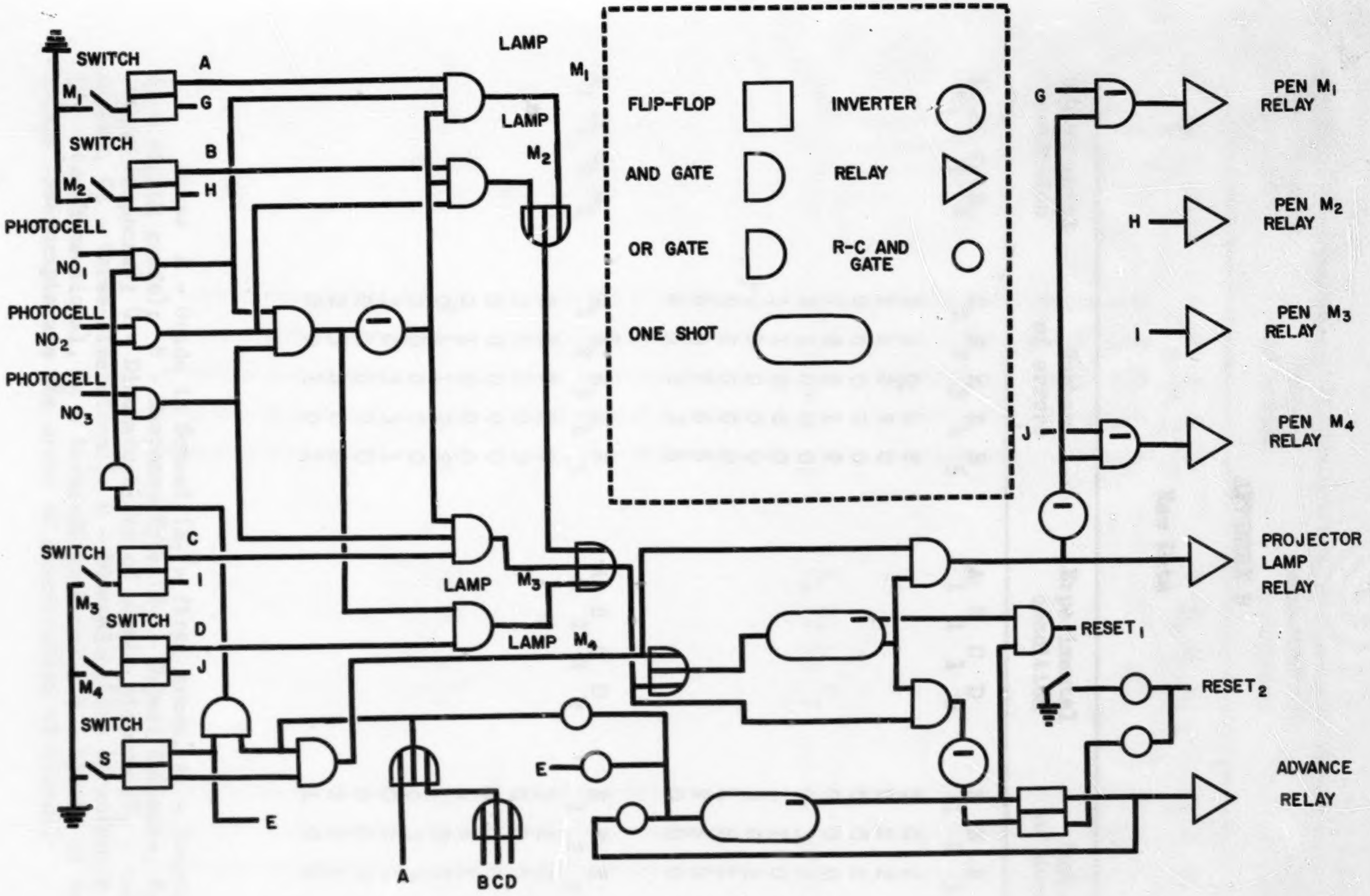
Conclusions

The difficulty in relating the results of this study to the literature in concept learning may be interpreted by some as evidence of the validity of Hunt's warning against the use of complex stimulus materials which have referential value to objects in real life situations. The experimenter offers an alternative explanation. Admittedly, studies that attempt to assess the communication of information, or more specifically, to investigate how stimulus variables affect the communication of names of concepts are involved with more complex processes than the experimenter in discrimination learning may be interested in handling. At the other extreme, is the audiovisualist attempting to advise teachers, film makers, book publishers, etc., how to make teaching materials more effective by using pictorial materials. The basis of the recommendations of the audiovisual expert have not been stated in a language such that empirical evidence can be obtained and accumulated for the purpose of evaluating the recommendations.

These comments should not be interpreted as arguments recommending the abandonment of either of these fields of endeavor. The intent of these statements is to argue that there is knowledge and there are techniques available to use as tools for working with stimulus materials which are relegated to the no-man's land between these two extremes. The hope is that such endeavors can borrow from both extremes and that an accumulation of information in mid-stream, like the building of a pier of a suspension bridge, will facilitate the construction of a span across the gaps. The logical analysis described in this report is one tool that seems promising as a language for discussing pictures and interpretations of them in terms of structures of information. A prediction based on the analysis was supported in the experiment reported. It needs to be applied to additional studies.

The main shortcoming of the present study is that the initial formulation of the experiment was done without sufficient consideration of the literature in the concept learning field. This is largely the explanation for the impossibility of relating the results of the study to the concept learning literature.

However, it will continue to be difficult to relate studies where such different stimulus materials are used. It does seem possible to use the findings from the study of simple stimulus materials to control more complex materials and thus in a given study to equalize some variables while others are compared. This kind of control should enable the accumulation of results which can be generalized to some population of materials. In most of the audiovisual research which has been done this has not been possible because of the complex uncontrolled nature of the materials. If results which are generalizable can be accumulated then it may be possible to see relationships between these studies and the fields of concept learning and audiovisual practices. The first need is to interest experimenters in working with this kind of stimulus material.


SWITCH
M1
A
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M4
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SWITCH
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BCD
LAMP
M1
LAMP
M2
LAMP
M3
LAMP
M4
E
FLIP-FLOP
AND GATE
OR GATE
ONE SHOT
INVERTER
RELAY
R-C AND GATE
G
H
I
J
PEN M1 RELAY
PEN M2 RELAY
PEN M3 RELAY
PEN M4 RELAY
PROJECTOR LAMP RELAY
RESET1
RESET2
ADVANCE RELAY

Appendix A. Wiring Diagram

APPENDIX B

Raw Data

Experimental condition	Number of errors					Experimental condition	Number of errors				
$A_1\ B_1\ C_1\ D_1$	E_1	E_2	E_3	E_4	E_5	$A_1\ B_1\ C_1\ D_2$	E_1	E_2	E_3	E_4	E_5
	3	3	0	4	2		0	0	2	0	0
	2	4	2	2	0		2	2	2	0	1
	0	0	0	0	0		0	0	0	0	1
	5	2	2	1	2		0	0	0	0	0
	2	1	0	0	0		5	3	2	3	2
	1	1	0	0	0		1	1	0	1	1
	0	0	0	0	0		2	0	2	0	0
	0	0	0	0	0		4	6	1	1	2
	4	4	5	6	5		2	5	4	2	0
	4	5	3	3	4		0	0	0	0	0
$A_1\ B_1\ C_2\ D_1$	E_1	E_2	E_3	E_4	E_5	$A_1\ B_1\ C_2\ D_2$	E_1	E_2	E_3	E_4	E_5
	2	3	0	2	0		3	2	0	0	0
	0	0	0	0	0		0	0	0	0	0
	0	0	0	0	0		0	0	0	0	0
	0	1	0	0	0		4	6	1	2	3
	0	4	1	2	2		1	3	0	0	0
	0	0	0	0	0		6	3	3	2	5
	3	0	3	3	1		0	0	0	1	0
	0	0	0	0	0		0	0	0	0	0
	2	3	4	0	0		2	2	1	1	1
	0	0	1	0	1		1	0	0	1	1

Note: A - Grade in School (A_1 - first grade, A_2 - fourth grade, A_3 - eighth grade); B - Response Type (B_1 - Object Response, B_2 - Relation Response); C - Dimensionality of sample picture (C_1 - two-dimensional, C_2 - three-dimensional); D - Dimensionality of matching picture (D_1 - two-dimensional, D_2 - three-dimensional); E - blocks of two trials (subscripts are the order of presentation of blocks)

Experimental condition	Number of errors					Experimental condition	Number of errors				
$A_1 B_2 C_1 D_1$	E_1	E_2	E_3	E_4	E_5	$A_1 B_2 C_1 D_2$	E_1	E_2	E_3	E_4	E_5
	2	0	0	0	1		5	5	5	5	5
	0	0	0	0	1		4	4	3	6	3
	0	1	1	0	1		4	3	2	4	3
	3	2	3	1	2		8	1	5	2	3
	5	0	2	4	4		1	3	3	3	3
	3	2	0	1	2		4	4	4	5	1
	5	2	1	2	1		3	4	3	4	4
	3	3	2	3	1		1	0	0	0	0
	3	1	0	0	3		4	3	1	1	4
	5	5	3	0	5		3	0	4	2	0
$A_1 B_2 C_2 D_1$	E_1	E_2	E_3	E_4	E_5	$A_1 B_2 C_2 D_2$	E_1	E_2	E_3	E_4	E_5
	4	3	3	1	3		4	4	0	3	2
	4	3	2	5	3		2	0	1	0	0
	5	4	5	1	2		3	5	4	5	2
	4	3	2	4	3		8	1	5	3	3
	3	2	5	2	4		3	3	4	6	2
	3	3	5	4	2		2	4	8	5	4
	3	4	2	6	3		4	4	4	6	2
	6	5	1	5	3		6	2	1	0	2
	4	5	1	0	0		4	5	5	4	3
	4	4	1	5	1		0	2	0	0	0
$A_2 B_1 C_1 D_1$	E_1	E_2	E_3	E_4	E_5	$A_2 B_1 C_1 D_2$	E_1	E_2	E_3	E_4	E_5
	2	0	0	0	0		4	2	0	0	0
	0	0	0	0	0		3	0	0	0	0
	0	0	0	0	0		3	2	4	3	0
	0	0	0	0	0		1	1	0	0	0
	1	0	0	0	0		1	1	0	0	0
	0	0	0	0	0		0	0	0	0	0
	0	0	0	0	0		1	1	1	0	0
	0	0	0	0	0		4	3	3	1	0
	0	0	0	0	0		1	0	1	0	0
	1	0	0	0	0		0	0	0	0	0

Experimental condition	Number of errors					Experimental condition	Number of errors				
A_2 B_1 C_2 D_1	E_1	E_2	E_3	E_4	E_5	A_2 B_1 C_2 D_2	E_1	E_2	E_3	E_4	E_5
	0	0	0	0	0		0	0	0	0	0
	0	0	0	0	0		0	1	0	0	0
	0	0	0	2	0		1	0	0	1	0
	0	0	0	0	0		1	0	0	0	0
	0	0	0	0	0		2	0	1	1	1
	1	2	5	1	4		0	0	0	1	2
	1	0	0	0	0		6	2	0	0	0
	0	0	0	0	0		1	0	0	0	0
	0	0	0	0	0		5	1	2	4	3
	4	0	0	0	0		4	0	0	0	0
A_2 B_2 C_1 D_1	E_1	E_2	E_3	E_4	E_5	A_2 B_2 C_1 D_2	E_1	E_2	E_3	E_4	E_5
	3	0	1	0	0		3	0	2	0	4
	4	1	2	6	0		2	1	0	0	0
	3	1	0	0	0		3	0	1	2	1
	4	4	1	3	1		2	4	5	3	1
	3	4	3	5	2		4	3	2	0	1
	4	3	3	5	6		0	3	0	0	0
	5	3	6	2	2		3	1	0	0	1
	2	4	0	0	2		2	1	4	3	2
	5	0	4	3	2		3	1	3	2	3
	3	2	0	2	3		3	0	1	0	1
A_2 B_2 C_2 D_1	E_1	E_2	E_3	E_4	E_5	A_2 B_2 C_2 D_2	E_1	E_2	E_3	E_4	E_5
	3	5	4	2	3		7	3	5	3	3
	5	4	3	3	5		1	0	0	0	1
	3	3	6	0	3		3	0	0	0	0
	6	4	3	3	2		3	0	0	0	1
	2	1	1	0	2		4	6	2	0	0
	4	3	0	2	0		1	0	0	0	0
	2	0	0	0	0		5	1	0	2	0
	5	1	0	0	3		7	2	3	2	2
	3	4	2	1	2		4	1	1	1	1
	3	6	4	4	3		1	1	0	0	0

Experimental condition	Number of errors					Experimental condition	Number of errors				
A_3 B_1 C_1 D_1	E_1	E_2	E_3	E_4	E_5	A_3 B_1 C_1 D_2	E_1	E_2	E_3	E_4	E_5
	2	0	0	0	0		1	1	2	5	3
	1	0	0	0	0		1	1	0	0	0
	0	0	0	0	0		1	0	0	0	0
	0	1	0	0	0		1	0	0	0	0
	0	1	0	0	0		2	0	0	0	0
	0	0	0	0	0		1	0	0	0	0
	1	3	0	0	0		0	0	0	0	0
	0	0	0	0	0		3	0	0	0	1
	1	2	0	0	0		0	0	0	0	0
	1	0	0	0	0		0	1	0	0	0
A_3 B_1 C_2 D_1	E_1	E_2	E_3	E_4	E_5	A_3 B_1 C_2 D_2	E_1	E_2	E_3	E_4	E_5
	2	0	0	0	0		1	0	0	0	0
	2	0	0	0	0		4	5	2	4	2
	4	1	2	0	0		3	2	0	4	2
	1	0	0	0	0		0	0	0	0	0
	3	1	2	0	0		1	3	2	0	0
	1	2	1	0	0		2	1	0	0	0
	3	0	0	1	0		0	0	0	0	0
	0	0	0	0	0		4	3	2	3	1
	0	0	0	0	0		5	5	2	2	0
	0	0	0	0	0		1	0	0	0	0
A_3 B_2 C_1 D_1	E_1	E_2	E_3	E_4	E_5	A_3 B_2 C_1 D_2	E_1	E_2	E_3	E_4	E_5
	0	0	0	0	1		3	3	0	5	1
	3	3	3	1	2		5	3	3	1	0
	2	0	0	0	0		0	1	4	1	4
	3	2	2	2	2		2	2	3	3	0
	1	0	1	1	0		1	2	0	0	0
	3	2	0	0	0		1	3	0	0	3
	1	0	0	0	0		6	4	1	0	0
	4	2	0	0	1		2	4	4	2	4
	3	0	0	0	0		6	0	1	0	0
	0	0	1	0	0		3	3	0	0	1

Experimental condition	Number of errors	Experimental condition	Number of errors
A_3 B_2 C_2 D_1	E_1 E_2 E_3 E_4 E_5	A_3 A_2 A_2 A_2	E_1 E_2 E_3 E_4 E_5
	4 2 5 6 1		1 0 0 0 0
	0 2 0 0 0		6 3 3 5 0
	2 0 0 1 2		3 0 0 0 0
	1 3 1 0 2		2 0 0 0 0
	3 6 1 0 0		2 0 1 0 0
	2 4 1 5 2		0 0 0 0 0
	3 3 0 3 0		0 0 0 0 0
	2 1 1 0 0		0 0 0 0 0
	3 0 2 0 0		3 1 3 2 1
	4 6 2 0 2		5 1 0 0 0

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